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PREDATORS VS PREY

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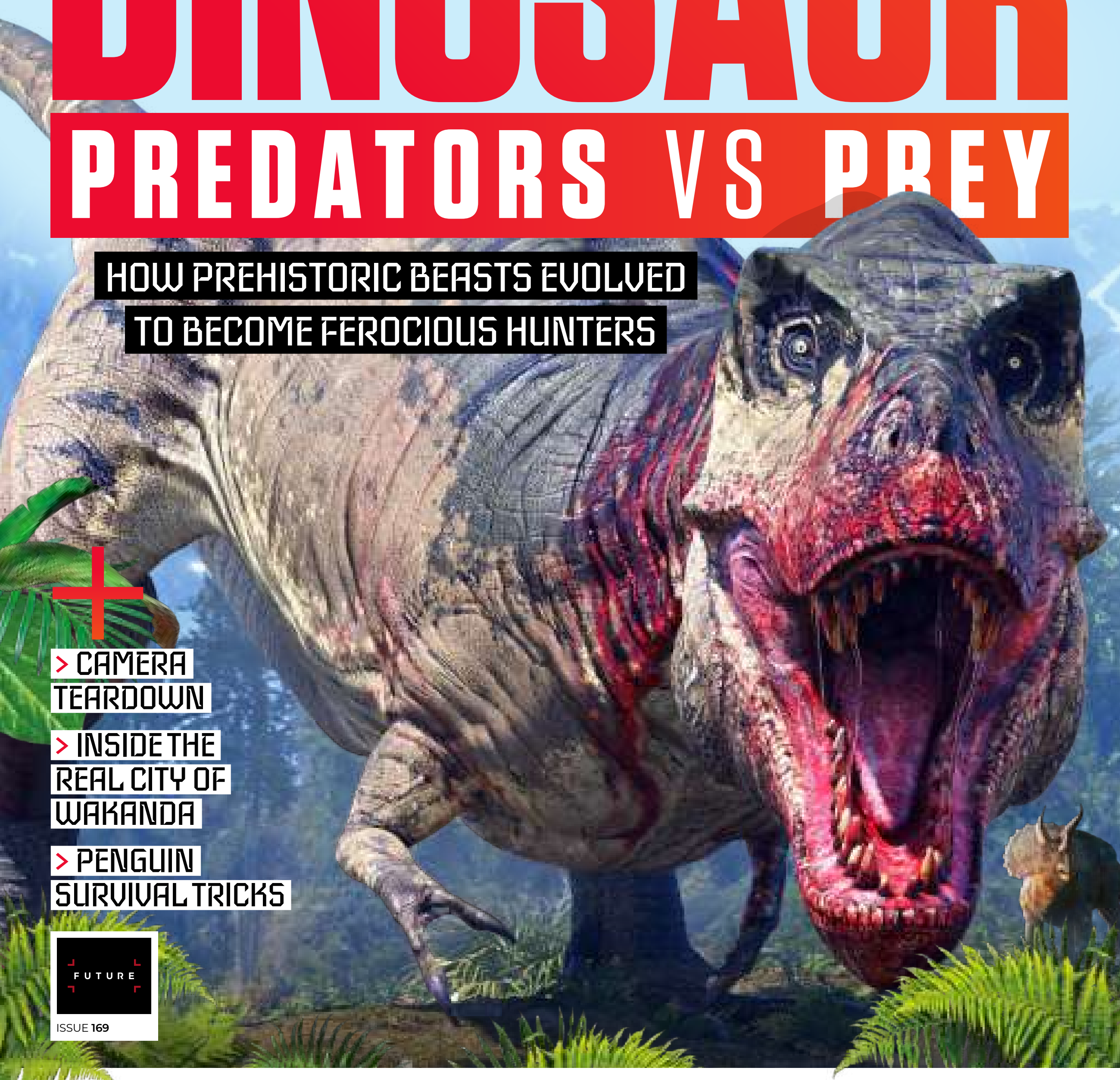

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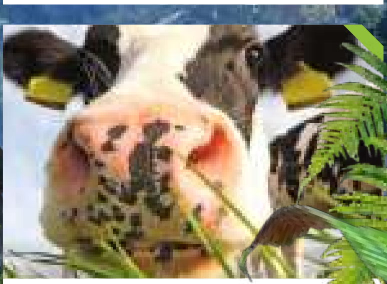

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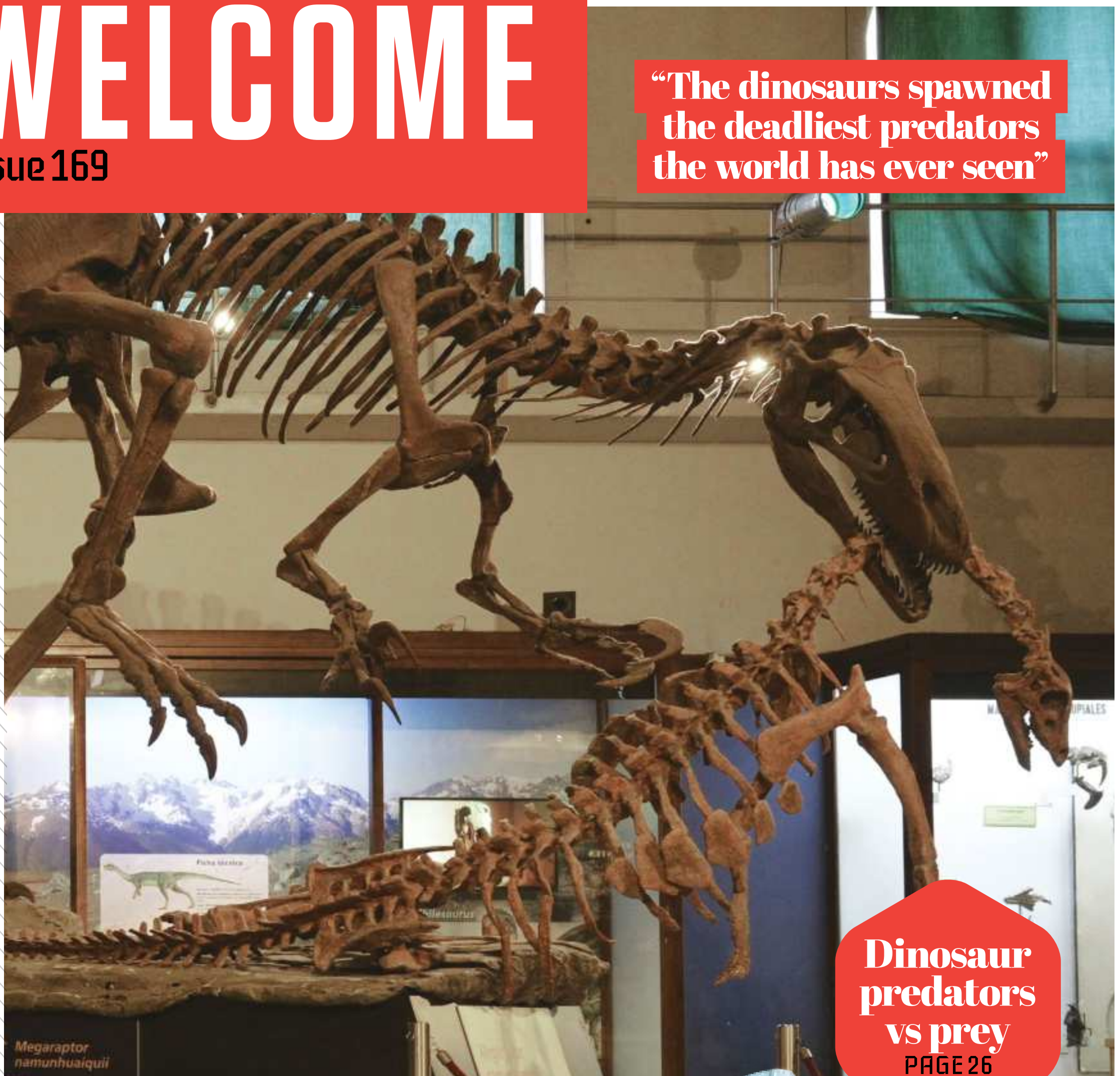

“The dinosaurs spawned the deadliest predators the world has ever seen”

Dinosaur predators vs prey

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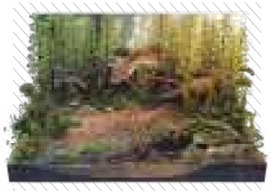
DINOSAUR
PREDATORS VS PREY

In May this year, palaeontologists announced the discovery of *Maip macrothorax*, the biggest known megaraptor – up to ten metres long from nose to tail – which terrorised what is now southern Argentina 70 million years ago. This fearsome carnivore didn’t just spring out of the dust during the Cretaceous era; it evolved from a long line of predators that can be traced back to over 500 million years ago. In this issue, we’re putting prehistoric apex predators under the spotlight to see where they came from, how they’ve changed over hundreds of millions of years and what a food chain during the age of the dinosaurs looked like on land and sea. Enjoy!

Ben Biggs

EDITOR

HIGHLIGHTS



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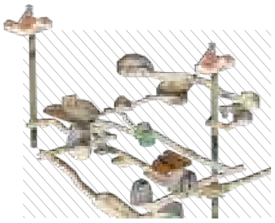

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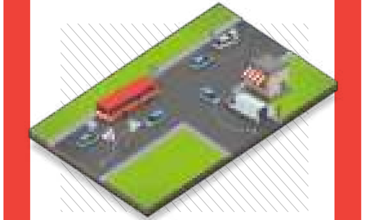

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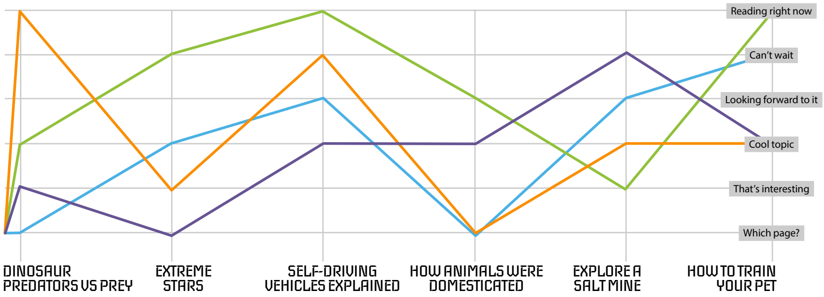

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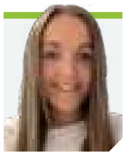

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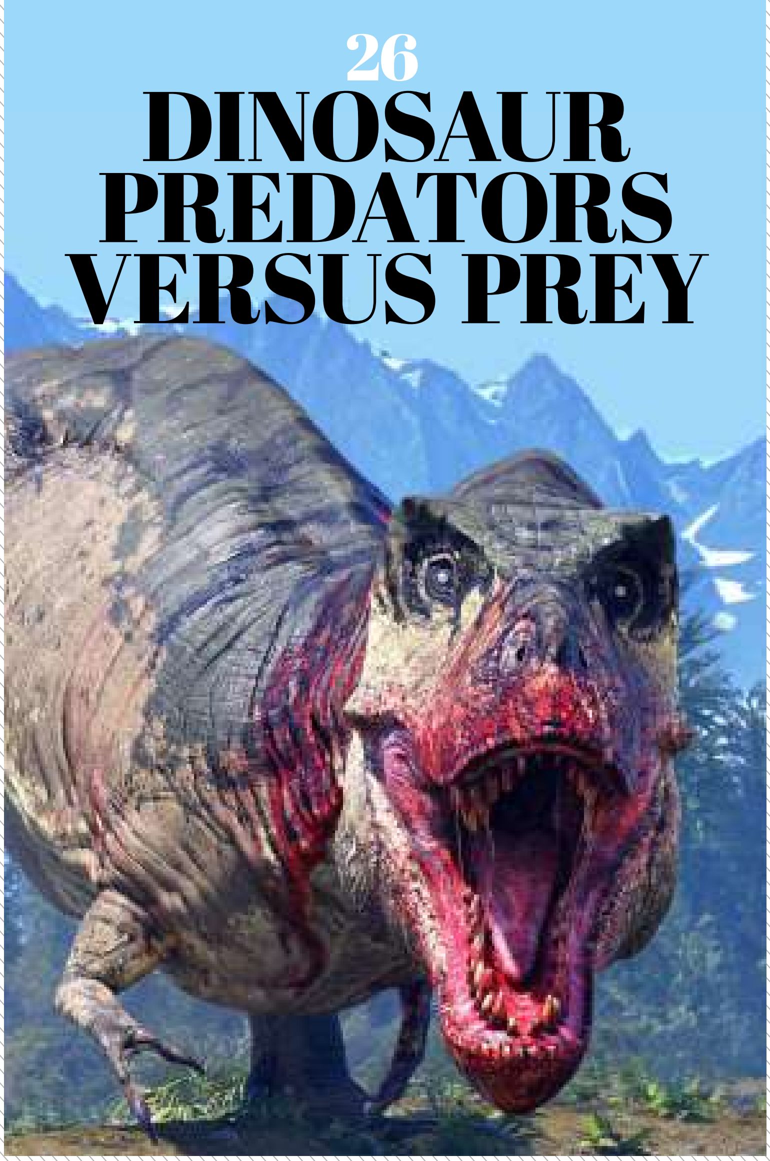

Win!
ONE OF TEN BUILD YOUR OWN PINBALL KITS
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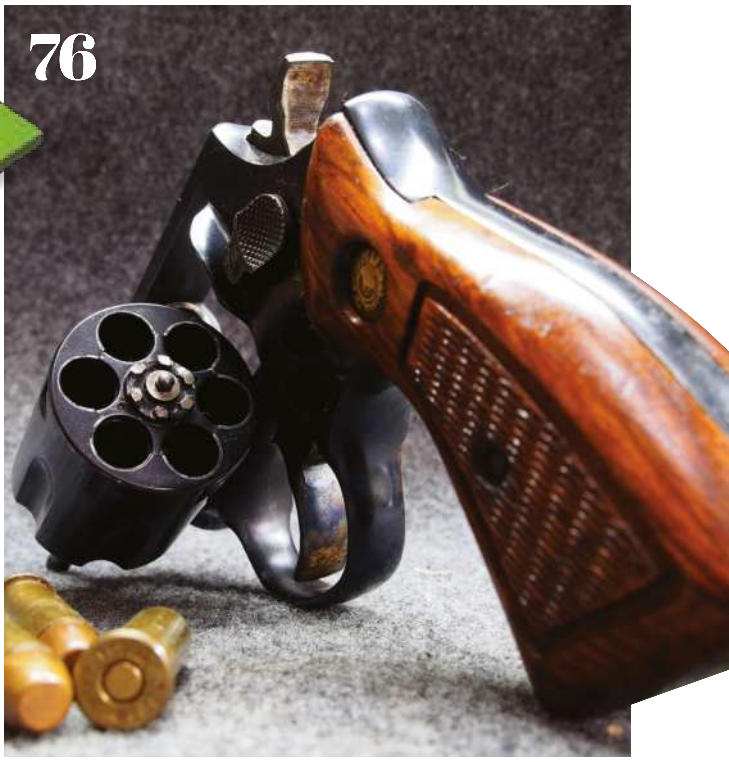
MEET THIS ISSUE'S EXPERTS

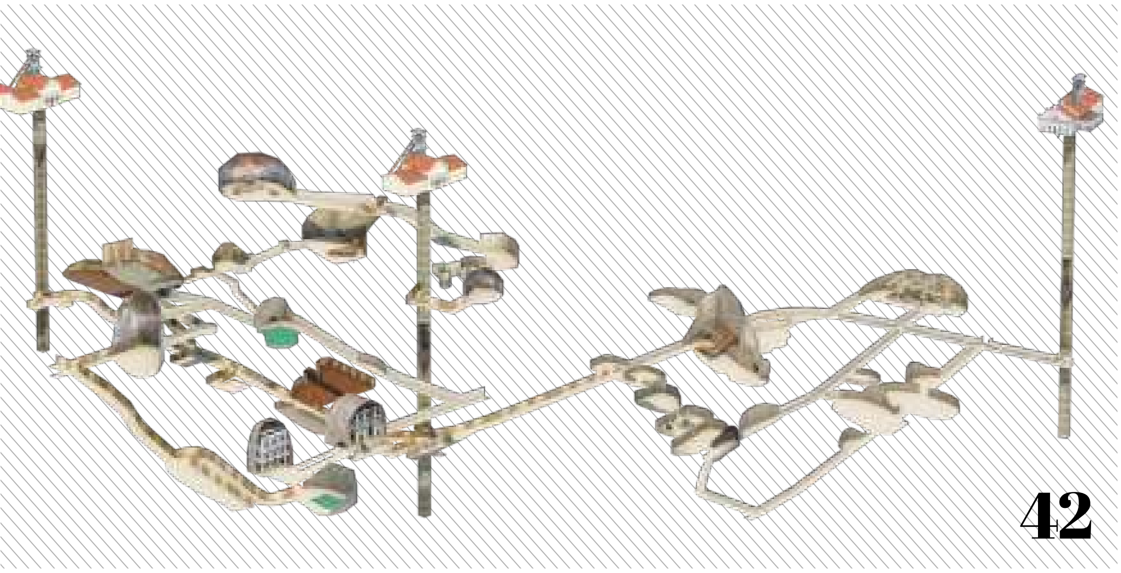
MIKE JENNINGS
Mike is a freelance technology journalist who is fascinated with gaming, futuristic technology and motorsport. He dreams of becoming a rally driver.

LAURA MEARS
Biologist Laura escaped the confines of the lab to the rigours of an office desk as a keen science writer and full-time software engineer.

JAMES HORTON
James works primarily in microbiology. He's an experienced science journalist, having written for a number of science magazines.

DR ANDREW MAY
Andrew has a PhD in astrophysics and 30 years in public and private industry. He enjoys space writing and is the author of several books.





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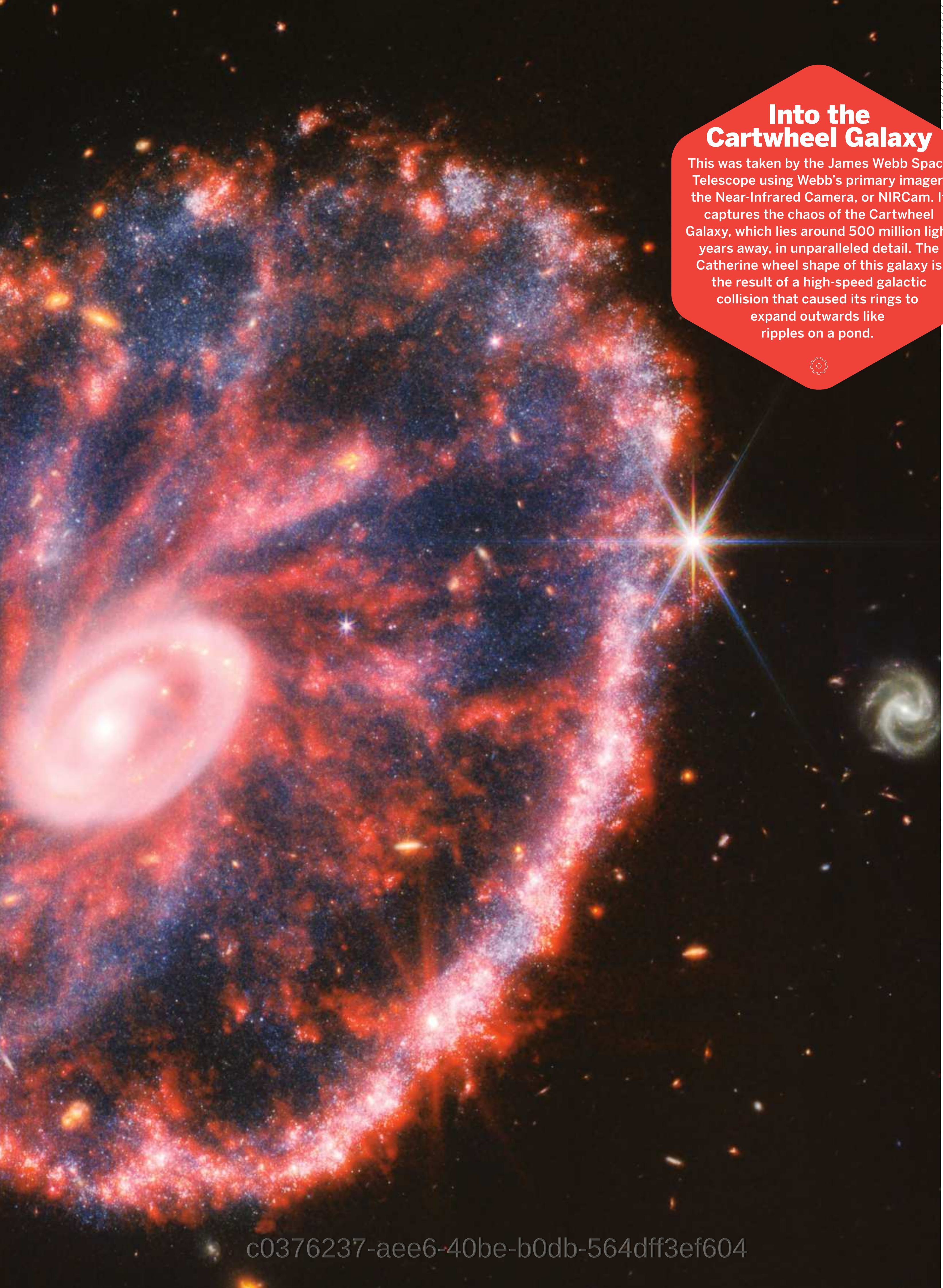

Into the Cartwheel Galaxy

This was taken by the James Webb Space Telescope using Webb's primary imager, the Near-Infrared Camera, or NIRCam. It captures the chaos of the Cartwheel Galaxy, which lies around 500 million light years away, in unparalleled detail. The Catherine wheel shape of this galaxy is the result of a high-speed galactic collision that caused its rings to expand outwards like ripples on a pond.

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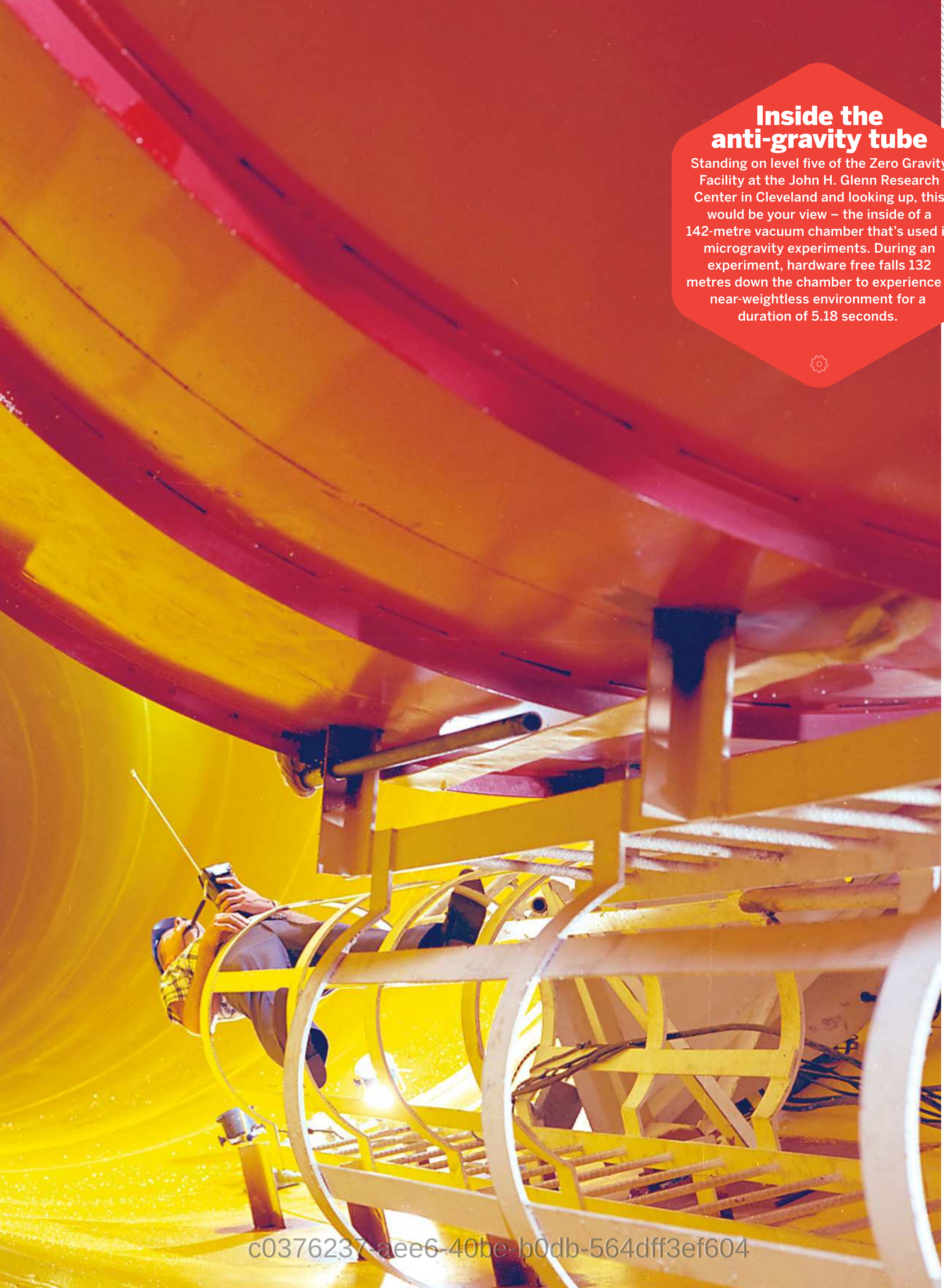

Inside the anti-gravity tube

Standing on level five of the Zero Gravity Facility at the John H. Glenn Research Center in Cleveland and looking up, this would be your view – the inside of a 142-metre vacuum chamber that's used in microgravity experiments. During an experiment, hardware free falls 132 metres down the chamber to experience a near-weightless environment for a duration of 5.18 seconds.

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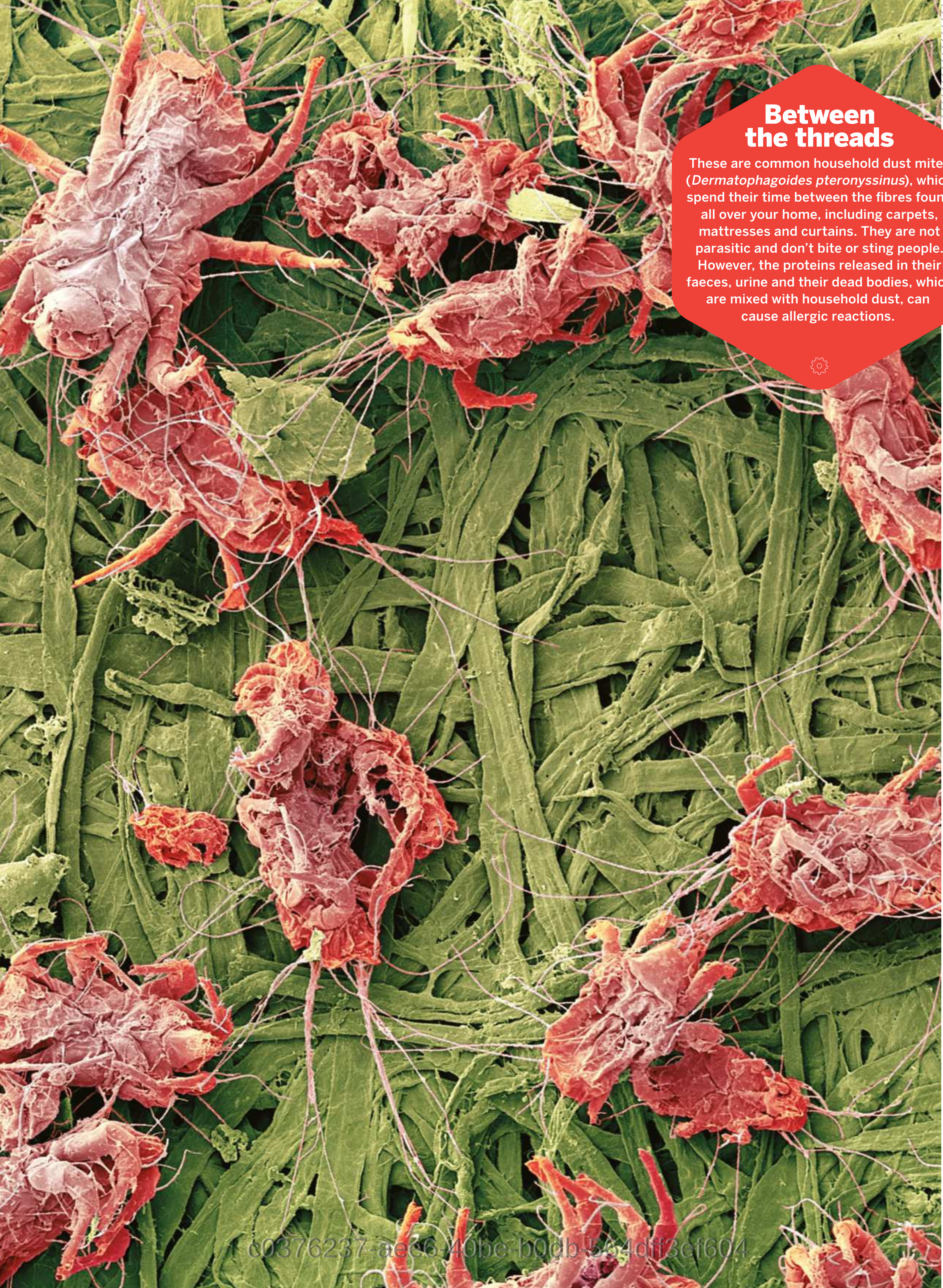

Between the threads

These are common household dust mites (*Dermatophagoides pteronyssinus*), which spend their time between the fibres found all over your home, including carpets, mattresses and curtains. They are not parasitic and don't bite or sting people. However, the proteins released in their faeces, urine and their dead bodies, which are mixed with household dust, can cause allergic reactions.

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Camel crossing

As the Sun sets over the Arabian Desert, the light casts an optical illusion onto the sand. Arabian camels are well adapted to life in barren deserts thanks to a single hump that holds up to 36 kilograms of water-storing fat. These camels can march in herds for up to 100 miles without needing to drink water. When they do need to drink, they can guzzle up to 114 litres of water in just 13 minutes.

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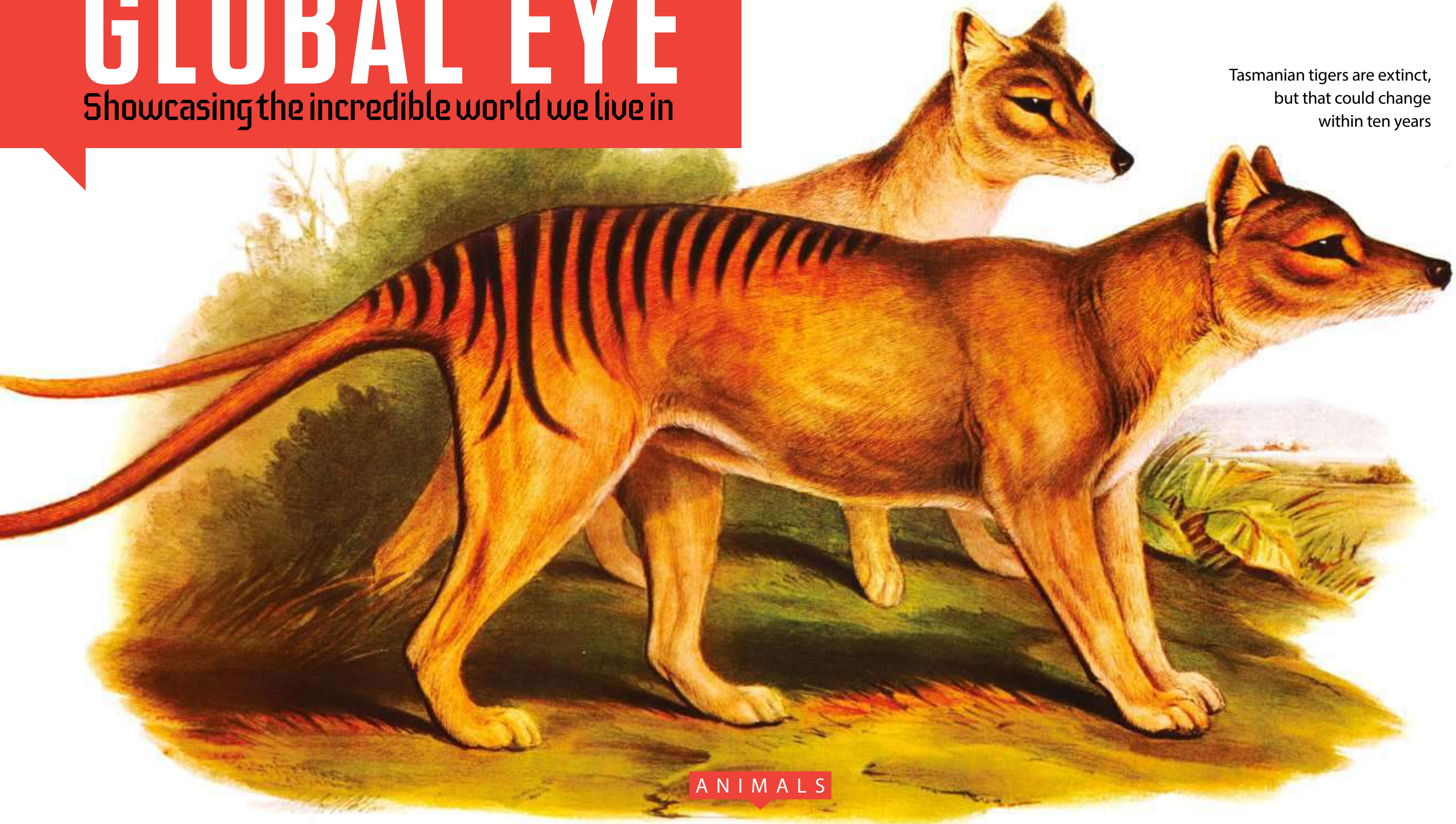


Tasmanian tigers are extinct, but that could change within ten years

ANIMALS

Scientists are bringing back extinct Tasmanian tigers

WORDS **MINDY WEISBERGER**

Can an extinct species be brought back to life? Scientists are taking a 'giant leap' in that direction by using gene-editing to resurrect the Tasmanian tiger, a carnivorous marsupial from Australia. It died out nearly a century ago, driven to extinction by human hunters and the introduction of non-native species to their grassland, wetland and forest habitats.

Researchers with the project, a collaboration between the University of Melbourne and the genetic engineering company Colossal Biosciences in Dallas, suggest that this so-called de-extinction could reinstall Tasmanian tigers (*Thylacinus cynocephalus*) to the wild within a decade, and could help restore balance to beleaguered Australian ecosystems where the animals once roamed. However, such efforts also raise questions about prioritising high-tech solutions for resurrecting animals that humans have already exterminated, while hundreds of species teeter on the brink of extinction today.

Scientists in the Thylacine Integrated Genomic Restoration Research (TIGRR) Lab at the University of Melbourne have already sequenced the thylacine genome from preserved thylacine DNA and pinpointed which living marsupials are most genetically similar to thylacines. Colossal's CRISPR gene editing technology will enable the group to take cells from a closely related living marsupial species, the fat-tailed dunnart (*Sminthopsis crassicaudata*), create a template genome, and then edit it to produce a thylacine genome and grow viable thylacine embryos.

"With this partnership, I now believe that in ten years' time we could have our first living baby thylacine since they were hunted to extinction close to a century ago,"' team member Andrew Pask, a professor of epigenetics at the University of Melbourne and leader of the TIGRR Lab, said in a statement. "We can now take the giant leaps to conserve Australia's threatened marsupials and take on the grand challenge of de-extincting animals we had lost."

Tasmanian tigers, or thylacines, appeared in Australia about 4 million years ago and were once widespread across the continent. Despite their name, they didn't look much like tigers; in fact, they were sometimes referred to as 'long dogs with stripes' because of their doglike heads and distinctively marked rumps. Thylacines had short ears and legs, and long, rigid tails, and were about the size of an American coyote, about 60 centimetres tall and weighing 17-20 kilograms.

Thylacines vanished from most of the Australian mainland about 2,000 years ago, and an estimated population of about 5,000 were in Tasmania around the time of European colonisation in the 1800s. But by the 1920s, thousands of Tasmanian tigers had been slaughtered by human hunters who mistakenly saw the marsupials as a threat to livestock. The last Tasmanian tiger seen in the wild was killed in 1930, and the last one in captivity – nicknamed 'Benjamin' – died in the Hobart Zoo in 1936.

According to researchers with the de-extinction project, resurrecting Tasmanian tigers would be a conservation success story; not only because it would restore a species that has been lost to human activity, but for building a lifeline for threatened species across Australia, "developing gestational and genetic rescue technologies for future marsupial conservation efforts," said Colossal CEO and co-founder Ben Lamm. "With our planet's biodiversity at risk, we will continue to contribute scientific resources to preserving the species and ecosystems necessary to sustain life."

Early medieval weapons and jewellery found in southwestern Germany near the Danube River

HISTORY

WEALTHY GERMAN STONE AGE AND EARLY MEDIEVAL GRAVES DISCOVERED

WORDS **STEPHANIE PAPPAS**

Archaeological treasures, including Stone Age pottery and medieval graves with swords and jewellery, have revealed a long history of human habitation near the Danube River in Germany. At the site, archaeologists discovered one grave from the Neolithic, or Stone Age, that dates to the 3,000 BCE and contains distinctive pottery from the Corded Ware culture. They also found 140 early medieval graves, dating to between 500 and 600 CE, containing goods including swords, lances, shields, drinking glasses and earrings. "Our Gutmadingen district is probably much older than we previously assumed," said Mayor Martin Numberger. The district had previously been dated to 1273 based on the first written records of settlement there.

The Stone Age grave points to the presence of The Corded Ware people. These people were probably pastoralists who kept animals such as cows and sheep, and some also practiced early farming of crops such as barley. The early medieval graves date to the century after the end of the Western Roman Empire, which fell in 476 CE.

SPACE

Europa's icy shell may be pure underwater snow

WORDS **STEPHANIE PAPPAS**

The shell of Jupiter's ice moon may be formed, in part, by pure underwater snow that floats up instead of down. A recent study has found that Europa's icy crust might be built partially by 'frazil ice', a fluffy accumulation of ice crystals. This holds a fraction of the salt found in ice that grows from the ice shelf itself, meaning Europa's ice sheets may be less salty than believed.

"When we're exploring Europa, we're interested in the salinity and composition of the ocean, because that's one of the things that will govern its potential habitability or even the type of life that might live there," said Natalie Wolfenbarger, a graduate student researcher at the University of Texas Institute for Geophysics.

Did you know?

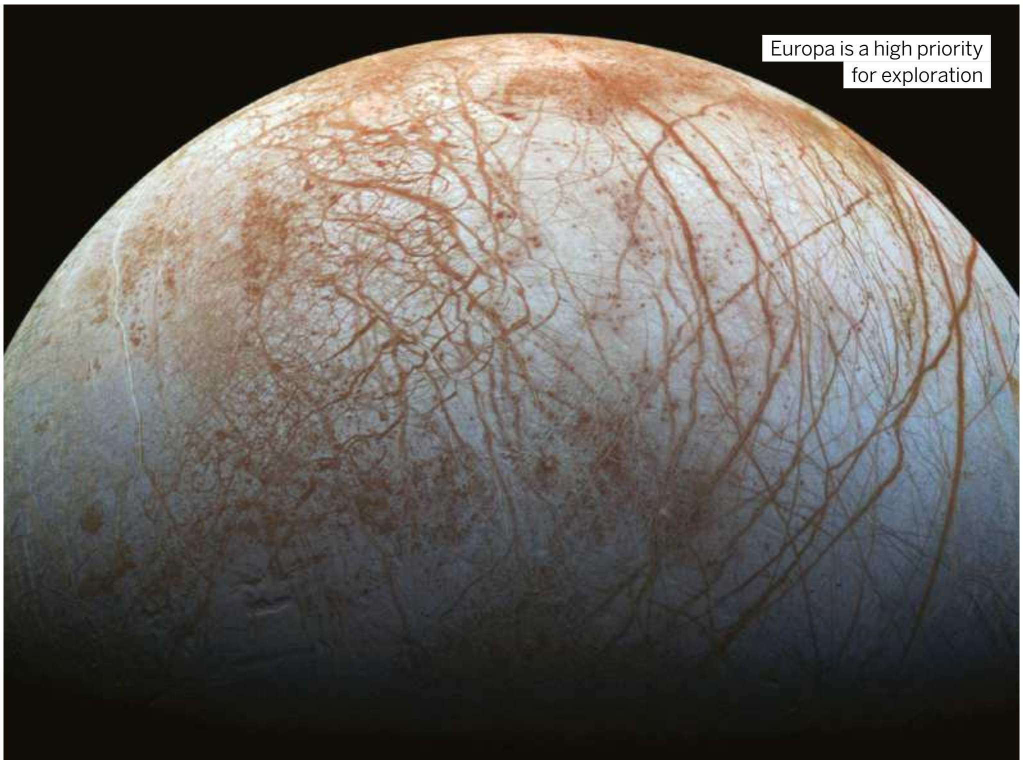
Europa is slightly smaller than Earth's Moon

For astrobiologists, Europa is an intriguing object. It is covered by an ocean 40 to 100 miles deep, capped by an ice crust 10 to 15 miles thick. It is a quarter of the size of Earth, but its ocean may hold twice the water as Earth's oceans, making it an intriguing place to search for extraterrestrial life.

A new NASA orbiter, Europa Clipper, is set to launch in October 2024 to see if it might be a suitable habitat for life. University of Texas at Austin scientists are leading the development of Europa Clipper's ice-penetrating radar instrument, which will peer into the ice sheet and ocean just beneath it. As part of that effort, the researchers wanted to understand how the ice sheet might be structured. They turned to Earth as an analogue, examining the two main ways ice forms under Antarctica's ice sheets. Congelation ice grows from the ice shelf surface, while frazil ice forms in cold seawater and drifts upward.

Europa likely has a low temperature gradient, meaning the temperature changes little with depth. In these conditions frazil ice is common. If frazil ice is also common on Europa, it could make a big difference in the composition of the moon's ice shell. While congelation ice might contain 10 per cent of the salt of the surrounding seawater, frazil ice contains only 0.1 per cent of the salt in the seawater it forms from. Not only could this affect the structure and strength of Europa's ice crust, it could impact how the Clipper's radar can penetrate the ice.

"This paper is opening up a whole new batch of possibilities for thinking about ocean worlds and how they work," said Steve Vance, a research scientist at NASA's Jet Propulsion Laboratory (JPL). "It sets the stage for how we might prepare for Europa Clipper's analysis of the ice."



Europa is a high priority for exploration

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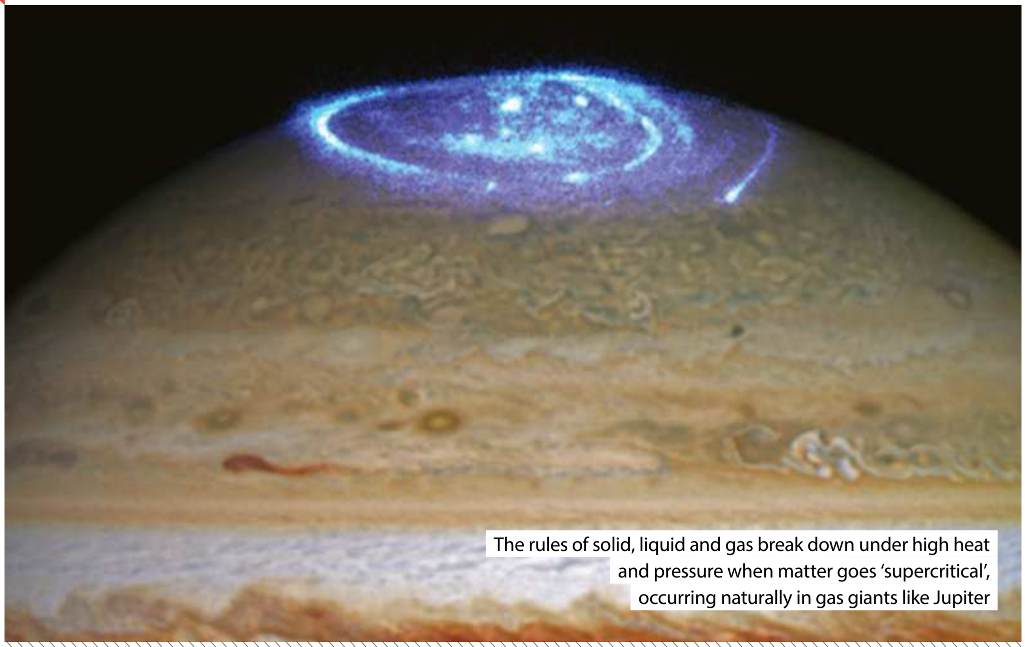


The rules of solid, liquid and gas break down under high heat and pressure when matter goes 'supercritical', occurring naturally in gas giants like Jupiter

STRANGE NEWS

Extreme physics of 'supercritical' matter may be simple

WORDS **STEPHANIE PAPPAS**

When under a great deal of heat and pressure, matter goes 'supercritical', and the difference between liquid and gas seems to disappear. Now, research finds that matter at this extreme supercritical state is less complicated than scientists previously thought. In fact, there are liquid-like and gas-like states in supercritical materials, and the tipping point between the two is surprisingly consistent across matter. This may mean there are universal rules governing these states across different types of materials.

"The asserted universality of the supercritical matter opens a way to a new, physically transparent picture of matter at extreme conditions," said Kostya Trachenko, a physicist at Queen Mary University of London. "This is an exciting prospect from the point of view of fundamental physics as well as understanding and predicting supercritical properties in green environmental applications, astronomy and other areas."

Supercritical fluids are already used in many industries. Because they combine properties of liquids and gasses, they can be employed in a number of chemical reactions and processes, such as hazardous-waste purification and oil extraction. They're also present in the atmospheres of Jupiter and Saturn.

Understanding the properties of matter in the supercritical state has not been easy, however. When the lines between solid, liquid and gas are blurred, what features of matter can explain its most important properties? Trachenko and Queen Mary postdoctoral researcher Cillian Cockrell zeroed in on two particular parameters: heat capacity, or how well a material absorbs heat, and the length at which a wave would propagate through the material.

The researchers found that when these two parameters are plotted against each other, there emerges a specific inversion point at which the properties of the supercritical material go from more liquid-like to more gas-like. What's more, this inversion point was similar in all of the supercritical systems the researchers studied. These included supercritical water, carbon dioxide, nitrogen, lead and argon – a group of substances ranging from metallic elements to noble gases. This is exciting from a basic science standpoint, Trachenko said, because it raises new questions about whether the inversion point can be explained by existing theories about transitions between different phases of matter or whether some new explanation will be needed.

"As we push the boundaries of what is known, we can identify these new exciting questions and start looking for answers," said Trachenko.

SPACE

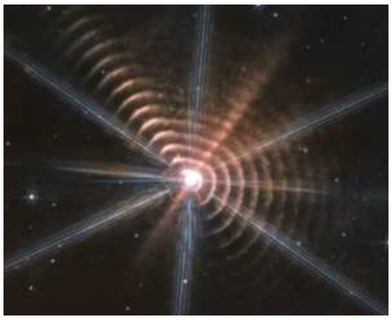
RIPPLES AROUND A DISTANT STAR PUZZLE ASTRONOMERS

WORDS **TEREZA PULTAROVA**

The James Webb Space Telescope captured mysterious concentric rings around a distant star that astronomers are still working to explain. The image was released on Twitter by citizen scientist Judy Schmidt. It shows a star known as WR140 surrounded by regular ripple-like circles that gradually fade away. The circles, however, are not perfectly round, but have a somewhat square-like feel, prompting speculation about alien origins.

Mark McCaughrean, an interdisciplinary scientist in the James Webb Space Telescope Science Working Group, called the feature 'bonkers' in a Twitter thread. "The six-pointed blue structure is an artefact due to optical diffraction from the bright star WR140 in this #JWST MIRI image," he wrote. "But red curvy-yet-boxy stuff is real, a series of shells around WR140. Actually in space. Around a star."

Astronomers will know more soon thanks to a scientific paper currently under review about this mysterious phenomenon. "Yes, those nested 'squircular' rings are real," Ryan Lau, an astronomer at NOIRLab, replied to the Twitter thread. "Our paper on this has been submitted so please stay tuned for the full story."



This image of strange concentric shells around the distant star WR 140 was taken by the James Webb Space Telescope

HEALTH

‘Forever chemicals’ can be destroyed by beheading

WORDS **STEPHANIE PAPPAS**

Synthetic compounds known as ‘forever chemicals’ because they never break down in the environment can actually be destroyed – by beheading them. Scientists discovered a simple destruction technique that works on 10 types of these chemicals, known as per- and polyfluoroalkyl substances (PFAS). Researchers hope that the method will expose weaknesses in even more PFAS-class substances, leading to paths for removing these chemicals from drinking water easily and cheaply.

PFAS compounds consist of a head, often containing charged oxygen molecules, and a tail of carbon and fluorine atoms, which are joined by a bond that nothing in nature can break. As a result, PFAS compounds persist in low levels in soil, air, water and even blood. Chemicals may interfere with the body’s hormones, raise cholesterol levels, affect fertility and increase the risk of certain cancers.

PFAS chemicals pass through water treatment plants unaltered, and current clean-up methods are prohibitively expensive. Filtering them and sticking PFAS chemicals in landfills raises the risk that they’ll leach out later, and other clean-up methods often produce harmful byproducts. Chemists at the University of California, Los Angeles and Northwestern University took a simpler approach – targeting the molecules’ heads with a chemical guillotine. Charged oxygen molecules are reactive with other chemicals, so Northwestern University chemist William Dichtel and doctoral student Brittany Trang decided to go after this weak spot.

The researchers used a common solvent, dimethyl sulfoxide (DMSO), because previous EPA research had hinted that PFAS slowly degrades when exposed to DMSO. Testing different recipes at different temperatures, Dichtel and his colleagues discovered that the fastest way to take PFAS down was to heat the ‘forever chemical’ to boiling along with DMSO and lye, or sodium hydroxide – a common chemical found in many types of soap. “That triggered all these reactions, and it started spitting out fluorine atoms from these compounds to form fluoride, which is the safest form of fluorine,” said Dichtel. “Although carbon-fluorine bonds are super-strong, that charged head group is the Achilles’ heel.”

Fluoride is safe for humans in small amounts and is often added to drinking water to help prevent tooth decay. The other byproducts of the reaction are carbon dioxide and formic acid. Because the new method doesn’t produce harmful chemicals, it could be used to clean drinking water. PFAS compounds could be filtered away and then beheaded, leaving behind only harmless chemicals. The method can clean up any PFAS compounds containing oxygen-rich carboxylic acid heads, the researchers found. That doesn’t cover all classes of PFAS, but Dichtel and his colleagues are hopeful that their method might inspire new means of attacking more resistant PFAS chemicals.

PFAS compounds, or ‘forever chemicals’, contaminate water around the world. A new method could get rid of them

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An adult dugong feeds in shallow waters of the Red Sea, near Marsa Alam in Egypt

ANIMALS

Chinese dugongs now declared extinct

WORDS **MINDY WEISBERGER**

Dugongs, the pudgy marine mammals that once inspired homesick sailors' fanciful tales of mythical mermaids, are now extinct in China, new research shows. For hundreds of years, these gentle giants, commonly known as sea cows, have swum in Chinese waters, ripping up seagrasses on the ocean bottom with a flexible upper lip. But with no sea cow sightings confirmed in the region for more than two decades, an international team of scientists recently undertook an in-depth investigation, surveying local fishing communities across four Chinese provinces and searching for evidence of the missing dugongs (*Dugong dugon*).

Historical records of dugongs peaked around 1960 and then decreased rapidly from 1975 onward. No verified sightings by fishers, for instance, are recorded after 2008, and scientists in China haven't spotted a dugong in the wild since 2000. "Based on these findings, we are forced to conclude that dugongs have experienced rapid population collapse during recent decades and are now functionally extinct in China," the scientists wrote.

Dugongs have plump bodies, broad, droopy faces and a flattened, fluked tail like a dolphin's. Adults measure up to four metres long and can weigh more than 400 kilograms. They resemble manatees, which are also referred to as sea cows but while manatees inhabit freshwater ecosystems, dugongs dwell in shallow tropical ocean habitats from East Africa to Vanuatu. Sea cows nibble on seagrasses much as terrestrial cows graze in lush meadows on land, and they are the only marine mammals that subsists on an exclusively vegetarian diet.

Neither manatees nor dugongs resemble humans, let alone alluring women with long hair and fishlike tails. But sailors at sea likely glimpsed these animals only very briefly – just long enough to inspire fanciful accounts of mermaids diving beneath the waves. However, the real-world story of humans and dugongs is no fairy tale. Because dugongs graze near coastlines, they are often struck by boats and caught in fishers' nets, and human activities have dramatically reduced or destroyed their coastal habitats.

A handful of people have anecdotally reported seeing a dugong in Chinese waters in the last five years, but those sightings were never verified, the authors of the new study discovered in their surveys. So while it's possible that some individual dugongs may yet survive in the northern South China Sea, it's also likely that the recently spotted animals were misidentified or were stragglers belonging to more stable dugong populations near the Philippines. What's more, the study found that "the dramatic population decline experienced by the species in recent decades is highly unlikely to be halted or reversed under current conditions."

"The likely disappearance of the dugong in China is a devastating loss," said Samuel Turvey, professor at the Zoological Society of London's Institute of Zoology. "Their absence will not only have a knock-on effect on ecosystem function, but also serves as a wake-up call – a sobering reminder that extinctions can occur before effective conservation actions are developed."

Did you know?
Manatees have no external ears

ANIMALS

‘Merciless’ sea monster prowled the sea 66 million years ago

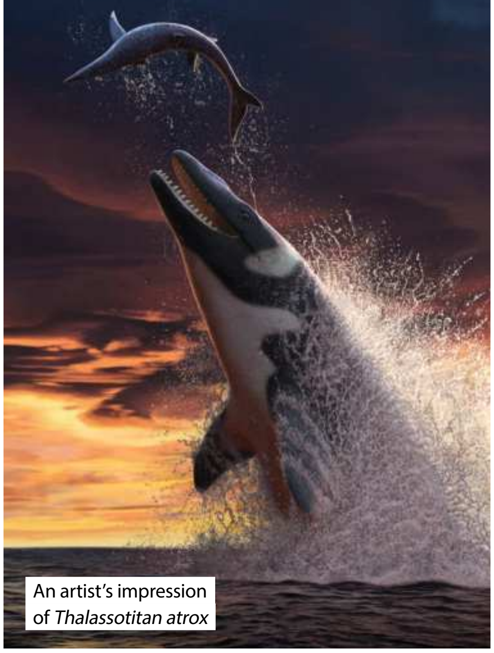
WORDS **PATRICK PESTER**

A giant mosasaur with teeth like a killer whale ruled the oceans around Morocco towards the end of the Cretaceous period, a new study finds. The extinct predator, named *Thalassotitan atrox*, grew to about nine to ten metres long and likely fed on any other marine reptiles it came across, including fellow mosasaurs. The name Thalassotitan comes from the Greek words ‘thalassa’ and ‘titan’, meaning ‘sea giant’, and the species name atrox translates to ‘cruel’ or ‘merciless’. Researchers discovered fossilised skulls, jaws and other remains that they used to identify *T. atrox* near Casablanca in western Morocco, an area that was underwater during the Cretaceous period. The researchers found that the teeth of *T. atrox* were often chipped, broken or worn down, suggesting the species damaged them while violently attacking and biting the bones of prey.

Mosasaurs went extinct at the same time as the dinosaurs after a giant asteroid struck Earth 66 million years ago. The new finds add to a fossil record in Morocco that shows the ocean there was teeming with rich and diverse life before the asteroid hit.

“They tell us how life was rich and diversified just before the end of the ‘dinosaur era’, where animals had to specialise to have a place in their ecosystems,” said Nour-Eddine Jalil, a collection manager at the Paleontology Research Center at the Museum of Natural History in Paris. “Thalassotitan completes the picture by taking on the role of the mega predator at the top of the food chain.”

Mosasaurs were a group of marine reptiles distantly related to modern lizards and snakes. They ruled the oceans for millions of years when dinosaurs dominated on land. A 2014 study estimated that one mosasaur specimen, from a different species in Russia called Mosasaurus hoffmanni, was about 17 metres long.



An artist’s impression of *Thalassotitan atrox*

The new species wasn’t the biggest mosasaur, but it was still a top predator and filled a similar role in its ecosystem to killer whales (*Orcinus orca*) and great white sharks (*Carcharodon carcharias*) today. Most mosasaurs had long jaws and slender teeth, but *T. atrox* evolved a shorter, wider muzzle that increased its bite force and short, conical killer whale-like teeth that could endure the increased forces when biting large prey.

The researchers found fossilised bones of at least three other mosasaurs in the same rock beds as *T. atrox* that showed signs of acid damage, suggesting these mosasaurs were digested in the stomach of *T. atrox* and spat out again.

© Getty / Andrey Atuchin

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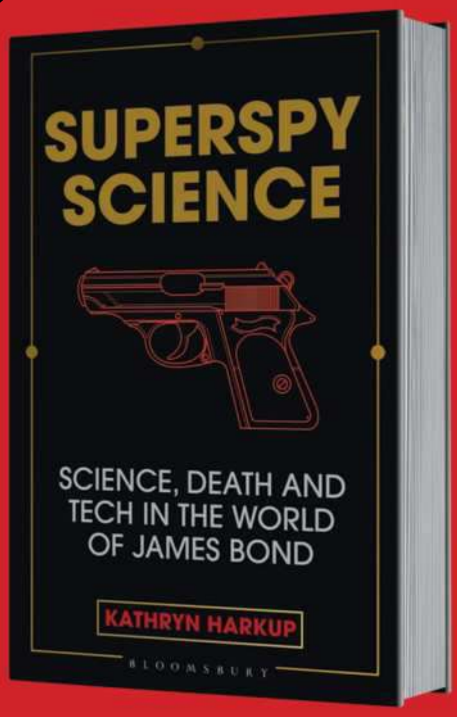


HEALTH

Your doppelgänger behaves like you, too

WORDS BEN TURNER

Somewhere out there, there's probably a person who has your face – and this unrelated lookalike may have more in common with you than just appearances. The surprising research, based on 32 pairs of unrelated doppelgängers from around the world, shows that two people who have a strong facial similarity to each other are also likelier to share significantly more of their genes and be more likely to share similar behaviors; but the genes that get switched on or off, and the microbial ecosystems in the two people's bodies, still differ.

These 'virtual twins' had never met, and were instead recruited thanks to the work of Canadian artist and photographer François Brunelle, who had been collecting pictures of lookalikes since 1999. "Our study provides a rare insight into human likeness by showing that people with extreme lookalike faces share common genotypes, whereas they are discordant at the epigenome [the genes which are switched on or off] and microbiome levels," said Manel Esteller, the director of the Josep Carreras Leukaemia Research Institute in Barcelona, Spain. "Genomics clusters them together, and the rest sets them apart."

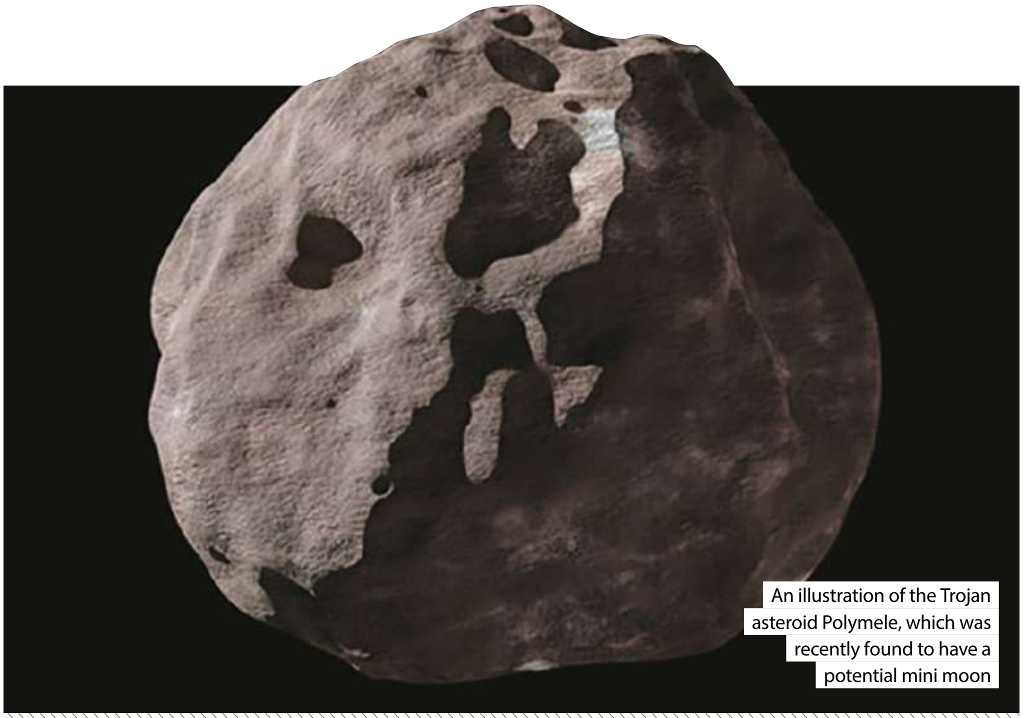
For the study, the 32 lookalike pairs completed a lifestyle and biometric questionnaire in their native languages, and the researchers used three different facial recognition algorithms to score the pairs' likenesses – of which half were considered doppelgängers by all three algorithms. Taking these 16 highly similar pairs, the researchers then investigated their genomic structure using DNA analysis. The analysis revealed that nine of the 16 pairs were 'ultra' lookalikes; they not only appeared closely related, they also shared 19,277 common genetic variations, called single nucleotide polymorphisms, or SNPs, in 3,730 genes. However, these extreme lookalikes were no more likely to share similar epigenetics or microbiomes than pairs that did not look alike.

Many of the lookalikes didn't just share some of their genetics either, but also had similar smoking habits, education levels and weights – a reminder that behaviour can be profoundly influenced by genes. "These findings do not only provide clues about the genetic setting associated with our facial aspect, and probably other traits of our body and personality, but also highlight how much of what we are, and what defines us, is really inherited or instead is acquired during our lifetime."

Perhaps most fascinating of all is that these genetic similarities between unrelated doppelgängers occurred by random chance, implying that the combinations the human genome can take are far from infinite, especially on a planet that is fast approaching a population of 8 billion people. The researchers say that their findings could be used in fields such as evolution, biomedicine and forensics.

"These results will have future implications in forensic medicine, reconstructing the criminal's face from DNA and, in genetic diagnosis, the photo of the patient's face will already give you clues as to which genome he or she has," Esteller said. "Through collaborative efforts, the ultimate challenge would be to predict the human face structure," based on genes and other factors.

Human genetic variation is far from infinite


An illustration of the Trojan asteroid Polymele, which was recently found to have a potential mini moon

SPACE

New mini 'moon' found lurking in the outer Solar System

WORDS **HARRY BAKER**

Astronomers may have detected a previously undiscovered 'mini-moon' in the solar system: a rocky object orbiting a small asteroid near Jupiter. If the rocky satellite, which is just a little wider than the width of Manhattan, is confirmed to be a proper moon, it would be one of the smallest moons ever spotted. The tiny satellite was discovered by scientists working on NASA's Lucy mission, which is sending a space probe to study some of the Trojan asteroids, two massive groups of space rocks that are located on each side of Jupiter on its orbit around the Sun.

The Lucy probe was launched on 16 October 2021, and will arrive at the Trojan asteroids in late 2027, after making a quick stop in the asteroid belt between Mars and Jupiter. Until then, Lucy mission scientists are trying to learn more about some of these mysterious rocks to help identify where the probe can be most useful. On 27 March, the smallest of Lucy's Trojan targets, known as Polymele, passed in front of a distant star, allowing mission scientists to accurately measure the space rock's size by observing how much of the star's light the asteroid blocked out as it whizzed past. However, researchers also observed an unexpected subsequent, smaller blip as a second asteroid followed in Polymele's wake.

After reviewing the data, it was concluded that the second blip "had to be a satellite," said Marc Buie, an astronomer at the Southwest Research Institute in Boulder, Colorado. The newly discovered satellite has a diameter of about three miles and is separated from the 17-mile-wide Polymele by a distance of around 125 miles. At the time of the observation, Polymele was around 480 million miles from Earth. "Those distances are roughly equivalent to finding a quarter on a sidewalk in Los Angeles while trying to spot it from a skyscraper in Manhattan," said NASA.

The term 'moon' can refer to any naturally occurring solid body that orbits a planet, dwarf planet or asteroid. More than 200 moons have been recognised in the solar system, not including asteroid moons, but the actual number is likely much higher. The researchers could make only fleeting observations of Polymele's satellite, so its orbital path is uncertain. As a result, the space rock cannot be officially designated as a moon or be properly named. But researchers are confident that when the Lucy probe arrives at Polymele, the spacecraft will be able to collect sufficient data to designate it.

Did you know?
Ganymede is bigger than Mercury

HISTORY

SCYTHIAN ARROWHEADS AND BRONZE AGE DWELLING UNCOVERED

WORDS **NICOLETTA LANESE**

Archaeologists in Ukraine recently uncovered a glut of arrowheads, spinning wheels and ceramic fragments dating back to the late 6th century and early 5th century BCE, a time when Scythian nomads, a culturally related group of nomadic tribes that occupied grassland between China and the northern coast of the Black Sea from about 800 BCE to 300 CE, occupied the area.

Remnants of Scythian culture can be found at the Bilsk Historical and Cultural Reserve near the village of Bilsk in central Ukraine. Human-made earthen ramparts can still be found, which many scholars associate with the ancient city of Gelonus, an important trading hub.

Archaeologists discovered 40 objects that date to the Scythian period, grain and garbage pits, and evidence of various economic buildings. The team has not uncovered any ancient dwellings, as "probably, they were destroyed during the development of a quarry that operated in this area in the past years," said Ihor Korost, director of the Bilsk Historical and Cultural Reserve, to Ukrinform. However, they did discover the remains of a late Bronze Age dwellingat a nearby site, predating the Scythian artefacts.

An example of a Scythian arrowhead, not found at the Ukrainian site

© Alamy / Getty / NASA's Goddard Space Flight Center

WISH LIST

The latest GAMES

PINBALL MACHINE

WWW.BUILDYOUROWNKITS.COM

£19.99 (APPROX. $23.10)

Build Your Own has recreated an arcade favourite with this action-packed kit. In around 60 minutes, players can construct the tabletop game using 61 press-out parts made from sustainable cardboard. There's no need for glue or tape to keep this game together, making it a fun project for children aged eight years old and over. Players can send a real marble spinning through the pinball machine using the spring-loaded launcher. While the marbles are whizzing around the cardboard ramps and vortex, players can ready the elastic-band operated flippers to send them flying back into the machine to achieve the highest score.

PINBALL MACHINE
OUT
PINBALL MACHINE
GO!
29cm
22cm
4.2cm

WINGSPAN

WWW.STONEMAIERGAMES.COM

£65 / $65

For bird lovers and wildlife enthusiasts of all ages, Wingspan is the multiplayer game that pits birds against each other to score the most points. Points are gained by completing goals over four rounds, such as having the biggest birds or the most eggs. One of the most appealing features of this game are the 170 beautifully illustrated cards depicting amazing avians from around the world. Although this is a great competitive game for up to five players, solo players can play alone against the deck. The game can take anywhere from 40 to 70 minutes to complete and is packed with strategic and fun avian information.

PLANET

STORE.BLUEORANGEGAMES.COM **£31.99 / $34.99**

Planet is a game of strategy and luck. Using magnetic continent tiles, players build an Earth made up of a 12-sided three-dimensional planet core model. As players move through the game they will collect different continent tiles that correspond with different habitats, such as oceans, woodlands and deserts. Continent tiles correspond to the requirements of different animals, and when you meet those requirements, you can place them on a player's fictional planet. The player with the most populated planet wins. Planet is a straightforward, fun game for players over eight years old.

BEASTS OF BALANCE

WWW.BEASTSOFBALANCE.COM

£99 (APPROX. $114.25)

Combining board games and digital gaming, Beasts of Balance is a simple stacking game that's packed with suspense. The aim of the game is to collect the most points using the integrated app by stacking animal characters, such as a shark, warthog and octopus, along with artefacts on a smart platform. Beasts of Balance is almost two games in one: on one hand players are taking turns to build a Jenga-like tower made of animals without them falling, while simultaneously playing a digital game on the accompanying app to populate a digital world of animals, prevent extinctions and boost their points.

APOLLO

WWW.BUFFALOGAMES.COM £29.99 / $18.99

Inspired by NASA's Moon missions, Apollo is a cooperative strategy game that explores spaceflight. The goal of the game is to complete a series of experiments and spaceflights. Players are given an astronaut each, while one player will take on the role of mission control, who controls the events within the game. Mission tasks include completing different flight stages, overcoming obstacles and making repairs to ships. Apollo is aimed at a slightly older audience with a more complex set of instructions and tasks to complete. Players win Apollo when all the stages of the missions are complete and the astronauts have successfully returned to Earth.

CHEMISTRY FLUXX

WWW.LOONEYLABS.COM

£15.99 / $16

Play with atoms and laboratory gear to create compounds and achieve goals in this fun draw-one-play-one card game. Don't worry, there's no need for any chemistry knowledge to play Chemistry Fluxx, but players might learn a bit about elements and compounds along the way. There are also some novel gameplay elements with certain cards. For example, if a player uses the helium card they need to be prepared to talk in a high-pitched voice for the remainder of the game. Whether you're a chemistry buff or just a fan of the Fluxx games, this scientific edition is both an educational and fun game for up to six players over the age of eight years old.

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DINO

PREDATORS VS PREY

Meet the most fearsome prehistoric creatures to roam the Earth and discover the food chains they depended on

WORDS **SCOTT DUTFIELD**

The ability to kill and ingest another living organism has been a keystone for the evolution of life as we know it. Without it, the world would be very different. Primitive organisms may have never emerged from the primordial soup at the beginning of life on Earth some 3.7 billion years ago. During life's complicated journey to the modern day, some organisms rose to the top of the food chain, feasting on the flesh of those below them. This predator-prey relationship is part of the natural machine that keeps every ecosystem on Earth functioning.

Predators got their start in the world's waters during the Paleozoic era, which started with the Cambrian period around 541 million years ago. Animals were confined to the oceans and had not yet sprouted legs to venture on land. One of the earliest predators were conodonts. These eel-like creatures were a few centimetres long with rows of rudimentary teeth scientists call elements. These were up to three millimetres in length and made of

Did you know?

There were around 700 different species of dinosaurs

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DID YOU KNOW? There's less time between the existence of humans and dinosaurs than between *Stegosaurus* and *T. rex*

SAUR

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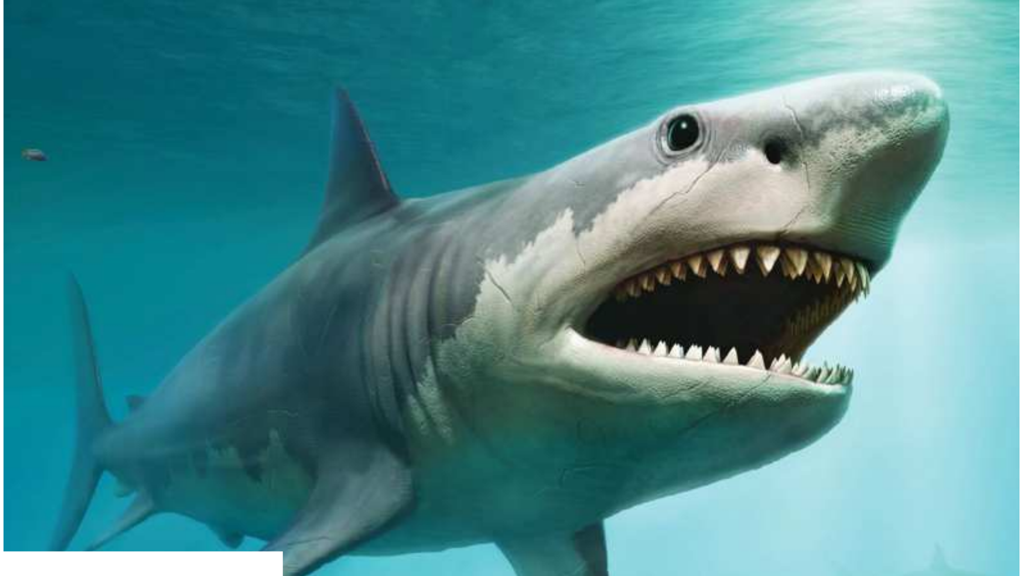
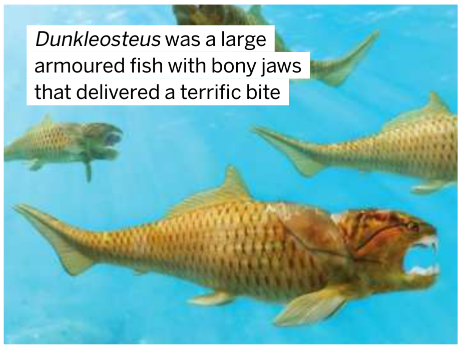


Sharks have been hunting longer than trees have existed

calcium carbonate. Conodonts were likely filter feeders and used their elements to prey upon tiny plankton for food.

Some unusual-looking early ocean predators were radiodonts. Some of these shrimp-like creatures used large curved appendages to tear through the tough exoskeletons of trilobite prey. The flesh of their benthic bounty was then manoeuvred by the appendages into a mouth opening directly beneath the head. During the geological periods that followed the Cambrian, diversity in Earth's oceans exploded. The Devonian period – 419 million to 358.9 million years ago – is often referred to as the 'Age of Fishes' and gave rise to some of the most menacing marine predators to have ever lived.

Prowling through shallow seas around the world about 360 million years ago were *Dunkleosteus*, four tonnes of armoured fish that measured around nine metres long. There have been ten different species of *Dunkleosteus* identified in fossil records from around the world, including in North American, European and Asian waters. What made these giant fish such formidable predators was their armoured heads. Much like a knight's helmet, *Dunkleosteus*' head was covered in external plates of bone that formed a sharp scissor-like edge at the mouth.



Dunkleosteus was a large armoured fish with bony jaws that delivered a terrific bite

> "There have been ten different species of *Dunkleosteus* identified in fossil records from around the world"

A *Dunkleosteus*' jaw could also deliver a bite with enormous force – around 55 newtons per square millimetre – which allowed it to feast on fish, early sharks and even other *Dunkleosteus*.

The Devonian also saw marine predators venture onto land, trading their fins for feet as they evolved. One of the earliest examples of a predator's transition out of the water occurred among amphibian tetrapods in four-legged vertebrates such as Ichthyostega. With the first pair of lungs, Ichthyostega was able to cross the boundary from sea to land. Although scientists may never know for sure why this evolution out of the water occurred, it's theorised that although Ichthyostega was likely a predator of fish, its ability to escape onto land may have allowed it to evade the threat of larger predatory fish.

Following in the webbed footsteps of Ichthyostega, throughout the Paleozoic more and more animals evolved out of the water and diversified into the next generation of land-based predators. By the final period of the Paleozoic era, the Permian period, predators were well established on land and had diversified into all shapes and sizes, including dog-sized carnivores called *Dinogorgon* and *Titanophoneus*, which are thought to have ambushed prey instead of chasing down a meal.

One of the most ferocious predators of the Permian period was the *Dimetrodon*. This creature had a massive sail that radiated along its back. Although it's unclear exactly why *Dimetrodon* sported a sail, it's thought that it may have been used to intimidate rivals or to regulate body temperature. Much in the same way elephants use their large ears to cool down the blood that passes through them, Dimetrodon may have pumped its cold reptilian blood through the sail to warm it up. Unfortunately, *Dimetrodon* and the majority of its fellow Permian predators met their end during the largest mass extinction event in Earth's history. Thanks to a period of excessive global warming, the world's oceans were depleted of oxygen, dropping to low levels of around two per cent. Depleted oxygen resulted in a massive disruption to prehistoric food chains that caused the eradication of 96 per cent of all marine life, along with 70 per cent of terrestrial

THE FIRST PREDATOR

Around 560 million years ago, the first predator emerged in Earth's prehistoric oceans. Named *Auroralumina attenboroughii* after British naturalist and broadcaster Sir David Attenborough, the anemone-like organism was uncovered in the UK in 2007. Devoid of any sharp teeth or piercing claws, the pioneering predator was a cnidarian, a group of animals that included corals and jellyfish. Much like its modern-day descendants, *A. attenboroughii* extended tentacle-like structures to capture passing food. Scientists believe that *A. attenboroughii* once fed on algae and zooplankton for survival. This creature is also the earliest known animal to have a skeleton, housing its densely packed tentacles.

A. attenboroughii was discovered in rocks containing fossils of other ancient species

Charnia
Auroralumina
Bradgatia
5 cm

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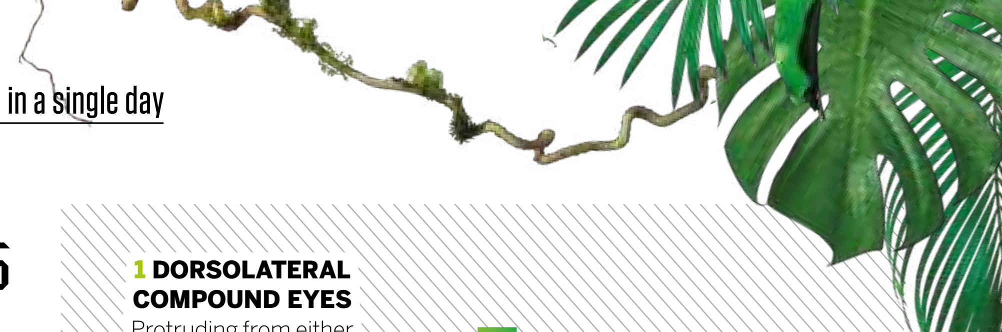
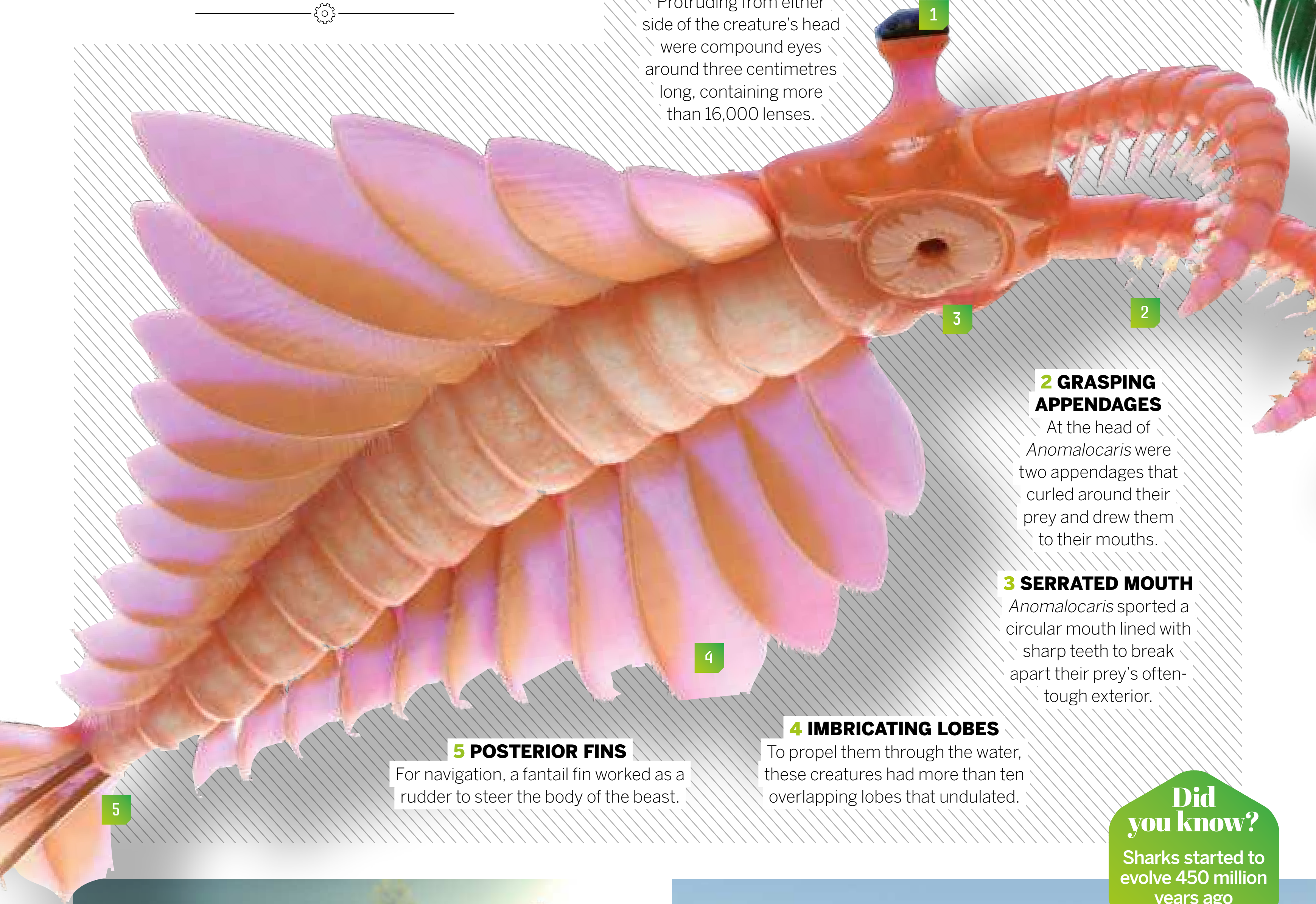
DID YOU KNOW? Quetzalcoatlus could fly around 400 miles in a single day



MEET ANOMALOCARIS

One of the first apex predators to swim in the oceans



1 DORSOLATERAL COMPOUND EYES
Protruding from either side of the creature's head were compound eyes around three centimetres long, containing more than 16,000 lenses.

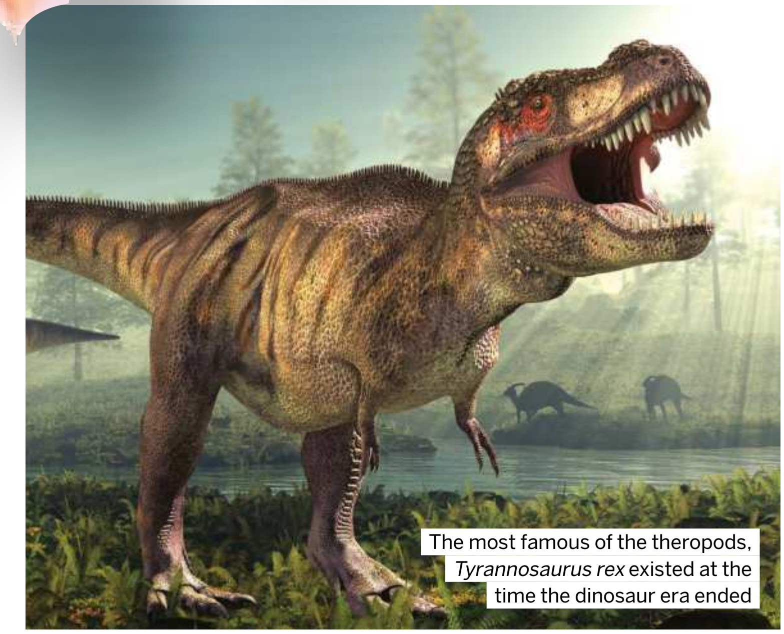
2 GRASPING APPENDAGES
At the head of *Anomalocaris* were two appendages that curled around their prey and drew them to their mouths.

3 SERRATED MOUTH
Anomalocaris sported a circular mouth lined with sharp teeth to break apart their prey's often-tough exterior.

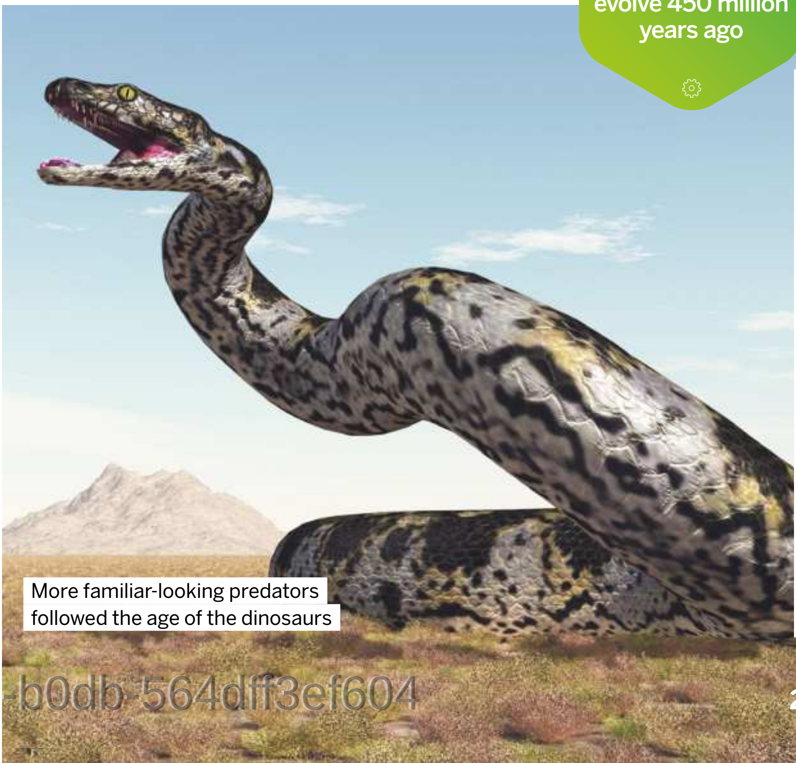
4 IMBRICATING LOBES
To propel them through the water, these creatures had more than ten overlapping lobes that undulated.

5 POSTERIOR FINS
For navigation, a fantail fin worked as a rudder to steer the body of the beast.

Did you know?
Sharks started to evolve 450 million years ago



The most famous of the theropods, *Tyrannosaurus rex* existed at the time the dinosaur era ended



More familiar-looking predators followed the age of the dinosaurs

© Getty / Wiki: F. S. Dunn, C. G. Kenchington, L. A. Parry, J. W. Clark, R. S. Kendall & P. R. Wilby

animal life, on Earth in an event referred to as the Great Dying or Permian-Triassic extinction event.

The reemergence of the apex reptilian predator came in the form of dinosaurs. From around 231 million years ago, during the Triassic period, dinosaurs ruled the land and seas. As the largest group of predators to have ever lived, these 'terrible lizards' were truly terrifying. The dinosaurs' reign began with small reptiles called saurischians, which consisted of both carnivores and herbivores. Over millions of years, the dinosaurs blossomed into a diverse group of animals, spawning the deadliest predators the world has ever seen.

Until the late Triassic, prehistoric predators had been restricted to the land and sea. However, a new group of animals emerged with large flaps of skin on their arms that acted like sails on the wind. Known as pterosaurs, these winged beasts were the first group of animals to take to the skies.

Did you know?

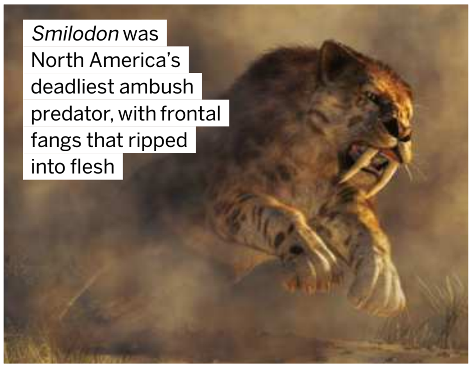
The first *Spinosaurus* fossil was found in Egypt

Although not technically a species of dinosaur, pterosaurs were cunning hunters with the ability to take an aerial view of the land and swoop down to snag their prey. By the last period of the Mesozoic era, the Cretaceous, pterosaurs had become giants in the sky – the very largest, *Quetzalcoatlus*, had a wingspan of 11 metres. They used this impressive wingspan to glide over the oceans and pluck fish swimming below.

Although these aerial aces were sizable predators, at the time *Quetzalcoatlus* soared through the skies, another colossal carnivore was stomping through the forests below. The *Tyrannosaurus rex* is one of the most instantly recognisable prehistoric predators. With all the notable traits of an apex predator, the *T. rex* was equipped with razor-sharp teeth, powerful jaws and a taste for meat. Like with many prehistoric animals, how it hunted is difficult to determine. Without being able to observe them in the wild, scientists must rely on fossil evidence to reveal the hunting tactics of the *T. rex*. Recent studies have suggested that giant reptiles' diets may have changed as they aged. As speedy juveniles, *T. rex* would have chased much quicker smaller reptiles as their prey. However, as an eight-tonne adult, *T. rex* were limited in their speed, reaching up to 25 miles per hour in short bursts. This meant that as adults their prey centred around much larger and slower prey to satisfy their giant appetites, such as the triple-horned *Triceratops*.

The *T. rex* is often portrayed as the biggest and baddest prehistoric predator to have ever roamed the Earth. However, there was another that overshadowed the *T. rex* – *Spinosaurus*. This enormous reptile towered over its prey at a whopping 5.4 metres tall and around 18 metres long, two metres taller than a *T. rex*. Unlike the tyrannical *T. rex*, *Spinosaurus* was a semi-aquatic dinosaur that spent its time hunting for prey underwater. According to fossil records, *Spinosaurus* had dense bones that allowed it to submerge itself in the water to pursue its prey. Its elongated snout also worked well to snatch any fish unfortunate to pass by with ease.

> **"With all the traits of an apex predator, the *T. rex* was equipped with razor-sharp teeth, a powerful jaw and a taste for meat"**



Smilodon was North America's deadliest ambush predator, with frontal fangs that ripped into flesh

The reign of prehistoric predators such as *Spinosaurus* and *T. rex* came to an end with the Cretaceous period some 66 million years ago following a huge meteorite impact. The massive explosion, followed by volcanic eruptions and earthquakes, made the ground tremble and filled the air around the world with toxic gases, wiping out around 75 per cent of all life on Earth. However, not all prehistoric predators met their end, surviving to live another day and ushering in the next generation of predators.

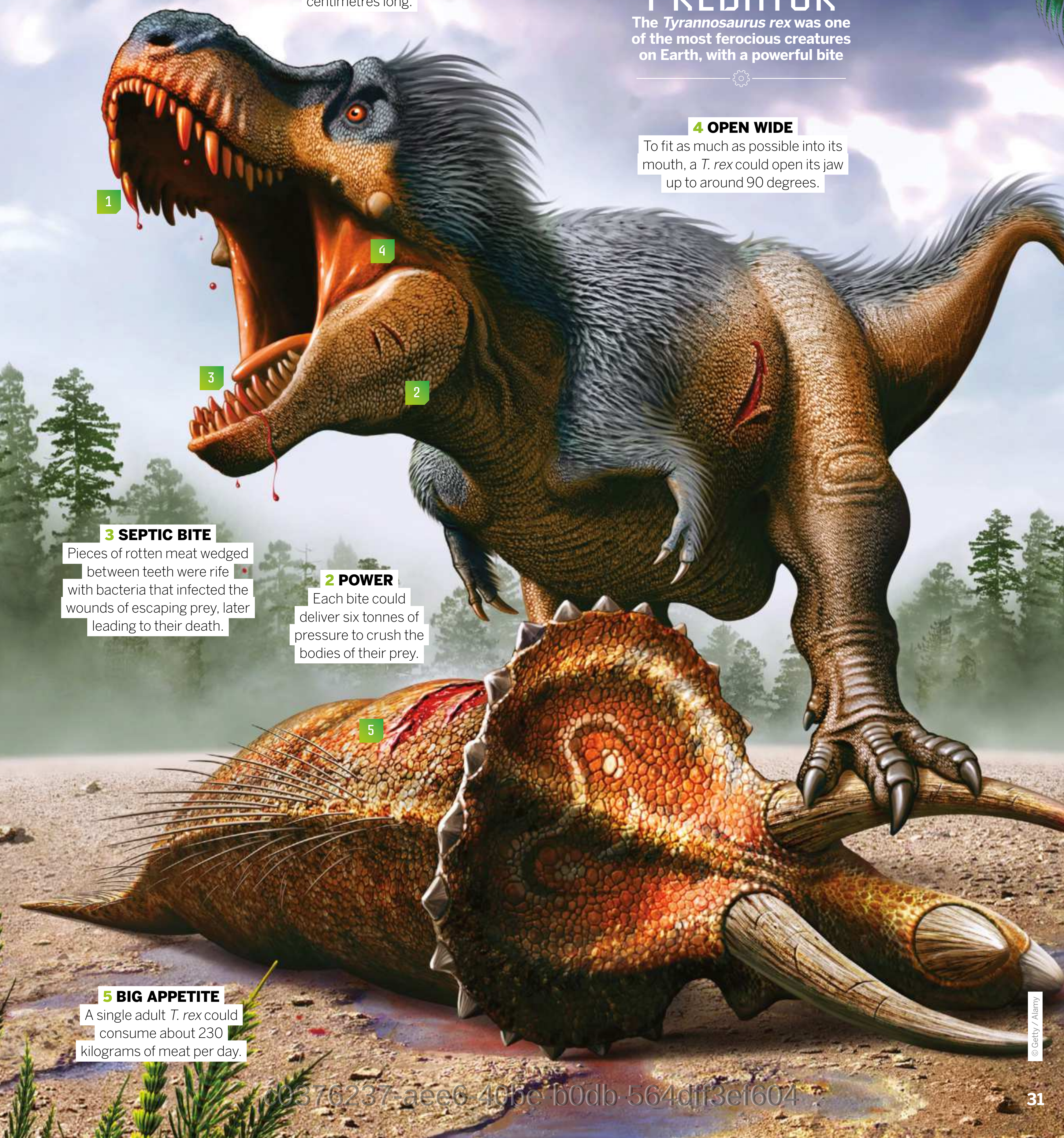
Although giant dinosaurs were now a thing of the past, the next – and current – era, called the Cenozoic, brought more predatory behemoths to Earth. One such terrifying example was the *Titanoboa*. Weighing in at around 1.3 tonnes, this 13-metre-long snake was the stuff of nightmares. Much like modern-day constrictors, *Titanoboa* likely killed its prey by ensnaring them in its suffocating coils and slowly swallowing them whole. Also during this era, the mighty megalodon emerged beneath the waves around 20 million years ago. These prehistoric sharks were giants of the sea, measuring up to 18 metres in length. As hardy predators, the mouths of megalodon were lined with hundreds of razor-sharp teeth. Because of the equally hardy prey they chose to dine on, these fangs would often become loose, break or fall away, but eventually they would be replaced. During its lifetime, a megalodon would shed around 40,000 teeth.

The Cenozoic was also when mammals came to the forefront as apex predators, such as the *Smilodon*, commonly known as the sabre-toothed tiger. These big cats sported two long canines that delivered a fatal blow to the necks of their prey, such as deer and camels, before tearing into the meat inside. These felines were wiped out of existence around 10,000 years ago, likely due to changing environments and possibly the emergence of human hunters – now Earth's most deadly species.

DID YOU KNOW? The largest carnivorous birds, *Brontornis burmeisteri*, were 2.8 metres tall

INSIDE THE MOUTH OF A PREHISTORIC PREDATOR

The *Tyrannosaurus rex* was one of the most ferocious creatures on Earth, with a powerful bite



1 PREHISTORIC TEETH

The mouth of a *T. rex* contained 60 serrated teeth, each around 20 centimetres long.

2 POWER

Each bite could deliver six tonnes of pressure to crush the bodies of their prey.

3 SEPTIC BITE

Pieces of rotten meat wedged between teeth were rife with bacteria that infected the wounds of escaping prey, later leading to their death.

4 OPEN WIDE

To fit as much as possible into its mouth, a *T. rex* could open its jaw up to around 90 degrees.

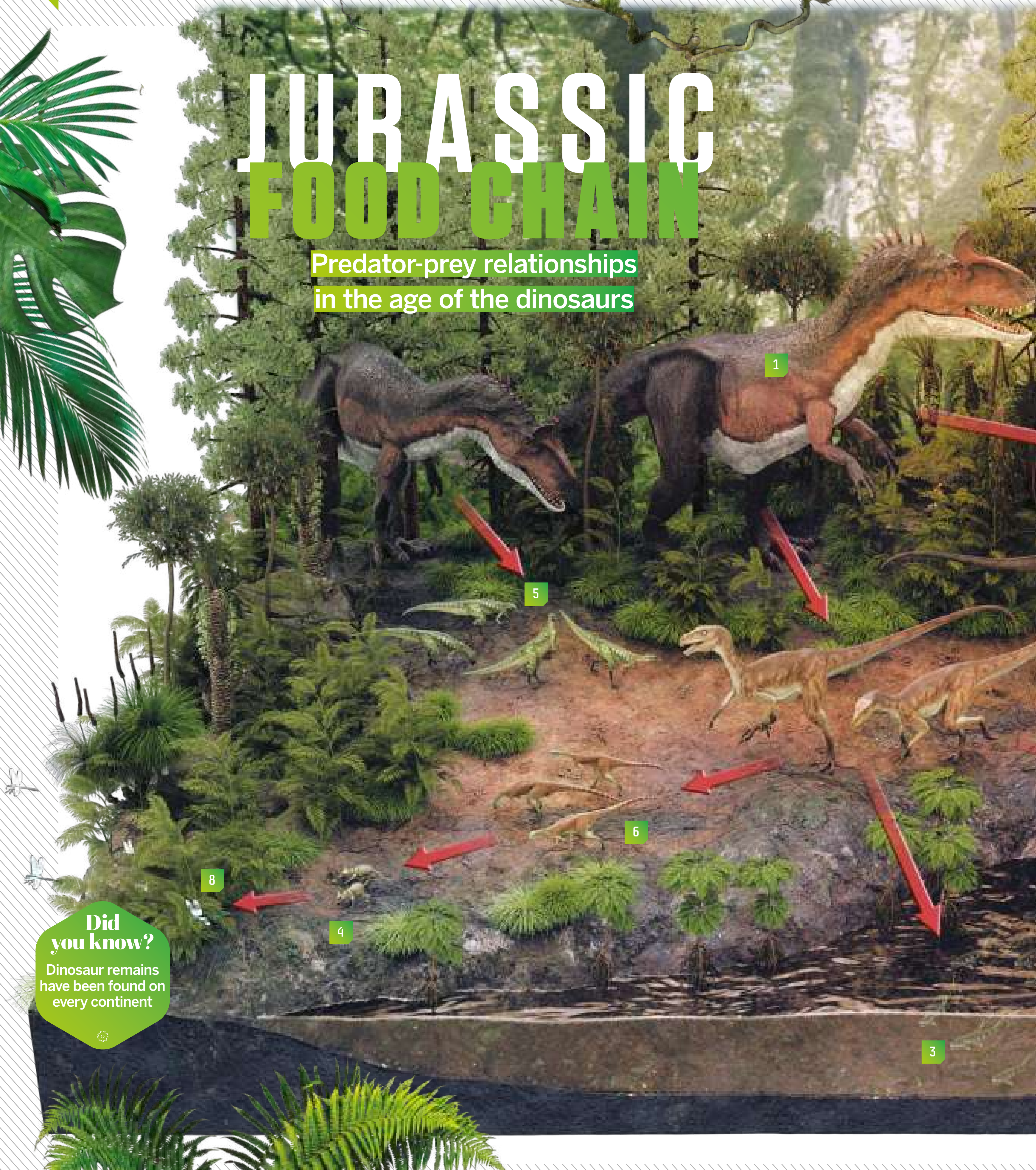
5 BIG APPETITE

A single adult *T. rex* could consume about 230 kilograms of meat per day.

© Getty / Alamy

JURASSIC FOOD CHAIN

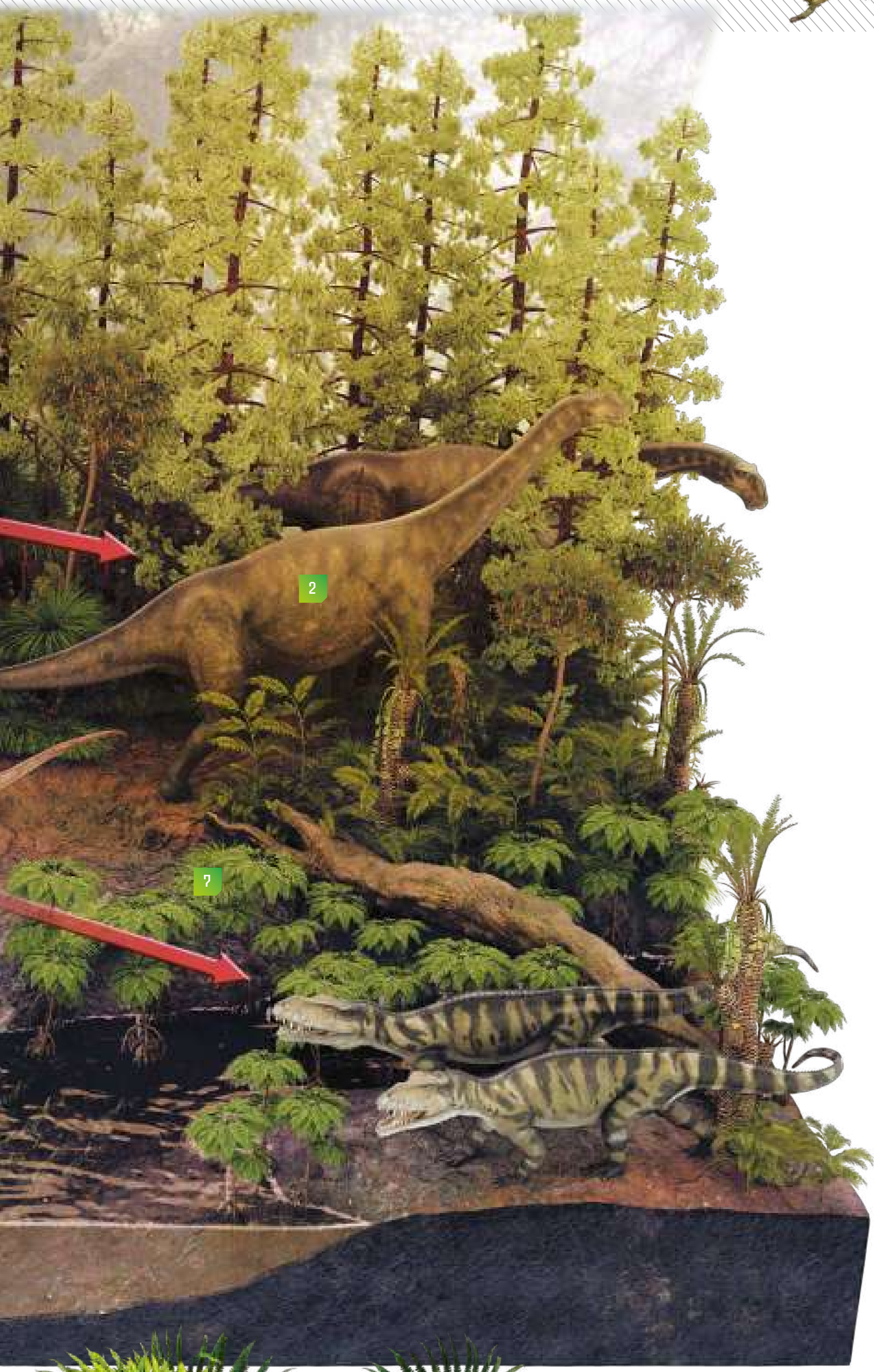
Predator-prey relationships in the age of the dinosaurs



Did you know?

Dinosaur remains have been found on every continent

DID YOU KNOW? Around 2.5 billion *T. rex* lived and died between 66 and 68 million years ago



1 APEX PREDATORS

At the top of the Jurassic food chain were predators like *Cryolophosaurus*. Prowling through the forests that once flourished on the Antarctic continent, these reptiles had a taste for smaller predatory reptiles and herbivorous sauropods.

2 GIANT HERBIVORES

Sauropod dinosaurs, characterised by their giant bodies, long necks and small heads, were hunted by much smaller carnivorous theropod dinosaurs such as *Cryolophosaurus* and *T. rex*.

3 FISH FOOD

Prehistoric ray-finned fish known as Palaeonisciformes were not only prey to underwater predators, but were snatched from the surface by theropods.

4 THE FIRST FURRY MEAL

During the early Jurassic period, the first furry mammals emerged, known as Mammaliaformes. These rodent-like creatures were a great snack for energetic theropod hunters.

5 PREDATORS EATING PREDATORS

Smaller theropod dinosaurs such as *Sarcosuchus* were both hunted by larger theropods and hunters of herbivorous dinosaurs.

6 VARIETY MEAL

Carnivores at the lowest end of the food chain likely had more variety in the species they preyed upon, including other carnivores, herbivores and omnivores.

7 PLANT-BASED

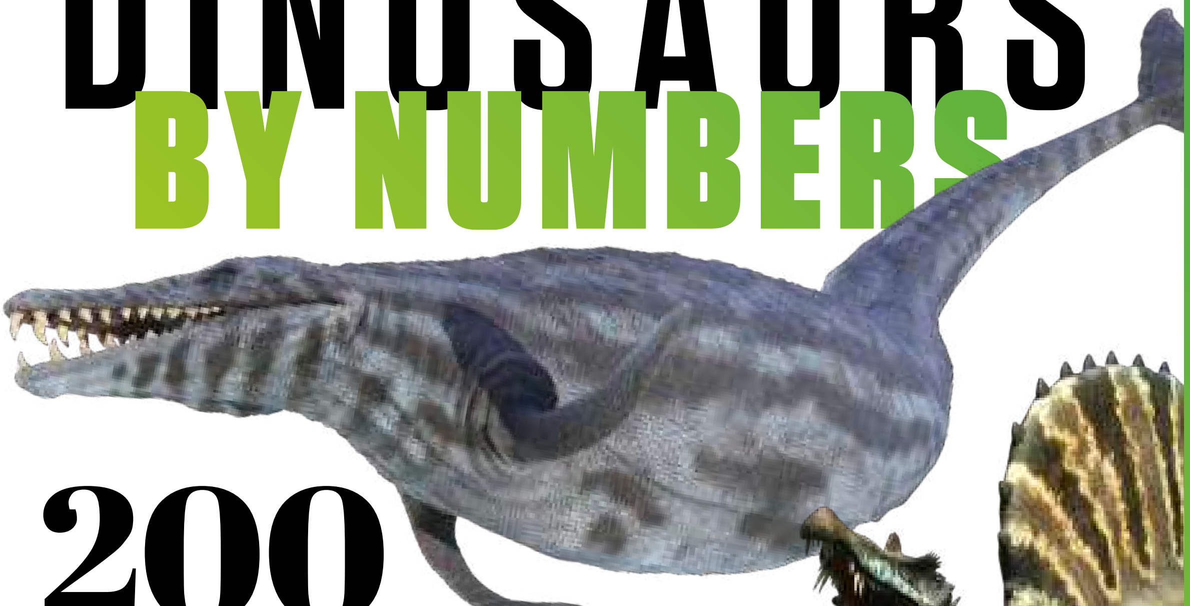
During the Jurassic period, herbivores feasted on ferns, conifers and ginkgos as the base-level producers of the food chain.

8 TINY PREDATORS

The first mammal predators were likely insectivores, hunting beetles and scorpionflies.

© Getty / Illustration by Nicholas Forder

DINOSAURS BY NUMBERS



200 TONNES

Basilosaurus was the largest prehistoric whale, weighing more than three Space Shuttles

1%

Carnivores were a minority in the collective dinosaur population

1,114 KILOGRAMS

In a single day, megalodon could eat over two-thirds the weight of a car in fish

Not all dinosaur predators had teeth. Oviraptorosaurs used a long beak and powerful jaw to crush bones

TOP TEETH

MEGALODON

LENGTH OF TEETH:
20 centimetres

NUMBER OF TEETH:
276

SPINOSAURUS

LENGTH OF TEETH:
12 centimetres

NUMBER OF TEETH:
64

CARCHARODONTOSAURUS

LENGTH OF TEETH:
8 centimetres

NUMBER OF TEETH:
64

TYRANNOSAURUS REX

LENGTH OF TEETH:
31 centimetres

NUMBER OF TEETH:
60

SABRE-TOOTHED TIGER

LENGTH OF TEETH:
31 centimetres

NUMBER OF TEETH:
26

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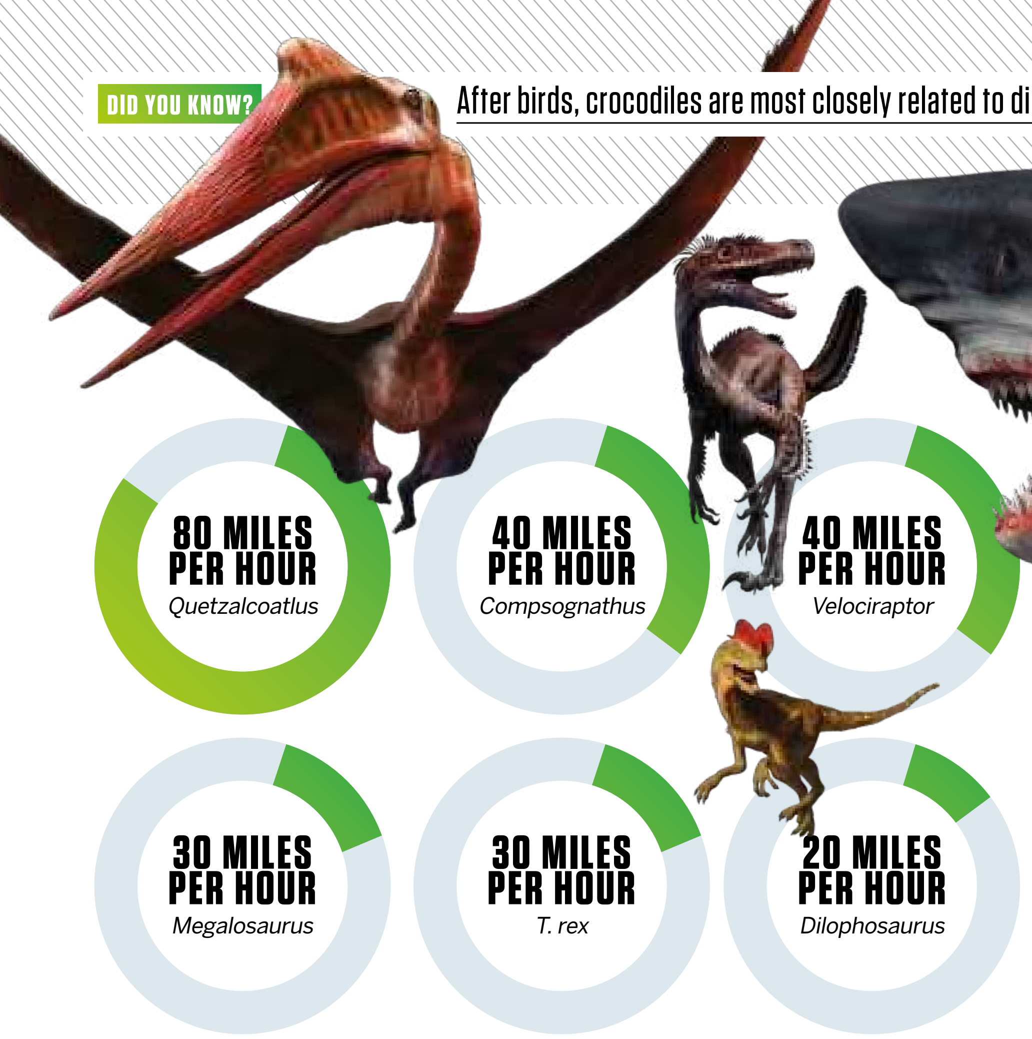
DID YOU KNOW? After birds, crocodiles are most closely related to dinosaurs



MEGALODON HAD A BITE FORCE OF 283 NEWTONS PER SQUARE MILLIMETRE

DINOSAUR TEETH WERE MADE UP OF LAYERS OF A TOUGH MATERIAL CALLED DENTINE

75 centimetres

Meganeuropsis permiana, the largest predatory insect, had a wingspan the height of a one-year-old child

20,000

Global population of *T. rex* before its extinction

TWO GRAMS

The smallest prehistoric mammalian predator, *Hadrocodium*, weighed the same as an almond

30 YEARS

The average life span of carnivorous dinosaurs

© XXXXX

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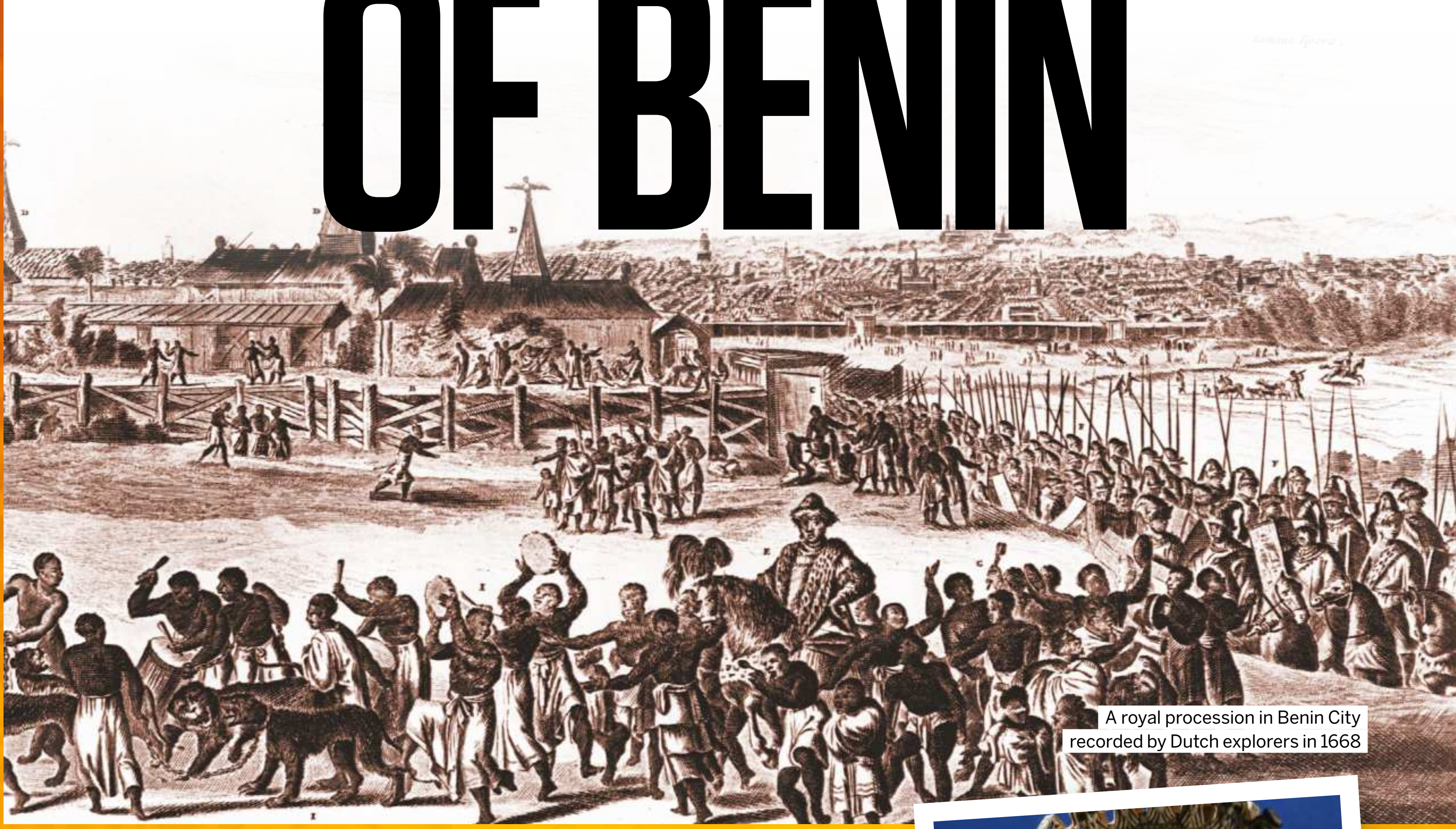
THE LOST CITY OF BENIN

The capital of Africa's Benin Empire astonished Europeans with its beauty, so why is there nothing left?



A royal procession in Benin City recorded by Dutch explorers in 1668

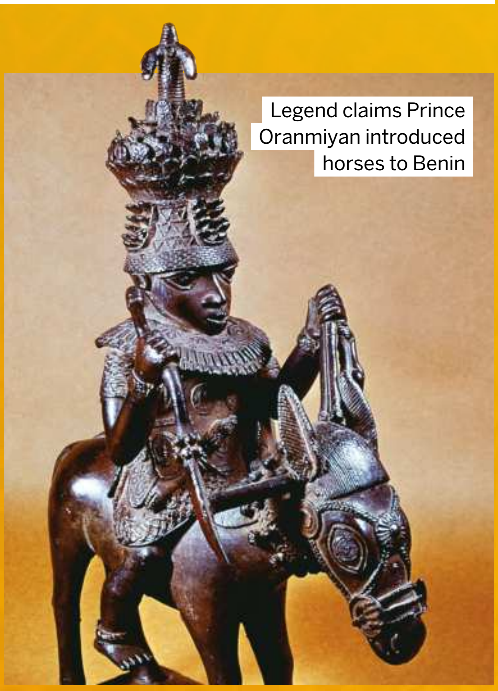
"Great Benin, where the king resides, is larger than Lisbon; all the streets run straight and as far as the eye can see," Portuguese ship captain Lourenço Pinto wrote of Benin in 1691. "The houses are large, especially that of the king, which is richly decorated and has fine columns. The city is wealthy and industrious. It is so well governed that theft is unknown and the people live in such security that they have no doors to their houses."

Located in the depths of the jungle but connected to other African kingdoms and the Atlantic Ocean by the Niger River, Great Benin City was the imperial capital of an empire that stretched from Lagos in the west to beyond the Niger in the east at its peak – an area that equates to approximately one-fifth of modern-day Nigeria.

Benin made contact with Europeans in the 1480s when Portuguese traders happened upon it while seemingly trying to find a way around the traditional Saharan trade routes. Dutch merchants arrived 100 years later, and over the next 200 years more traders came from England, France, Germany and Spain. They all returned home with amazing stories to rival Pinto's. But if you mentioned the Benin Empire to a westerner today – even someone from Portugal, which maintained regular contact with the kingdom for 400 years – they are likely to stare at you blankly. What happened to the Great City of Benin and why did it disappear without a trace?

Ornamental masks made up part of an Oba's regalia

DID YOU KNOW? Ewuare II is the current Oba


Legend claims Prince Oranmiyan introduced horses to Benin

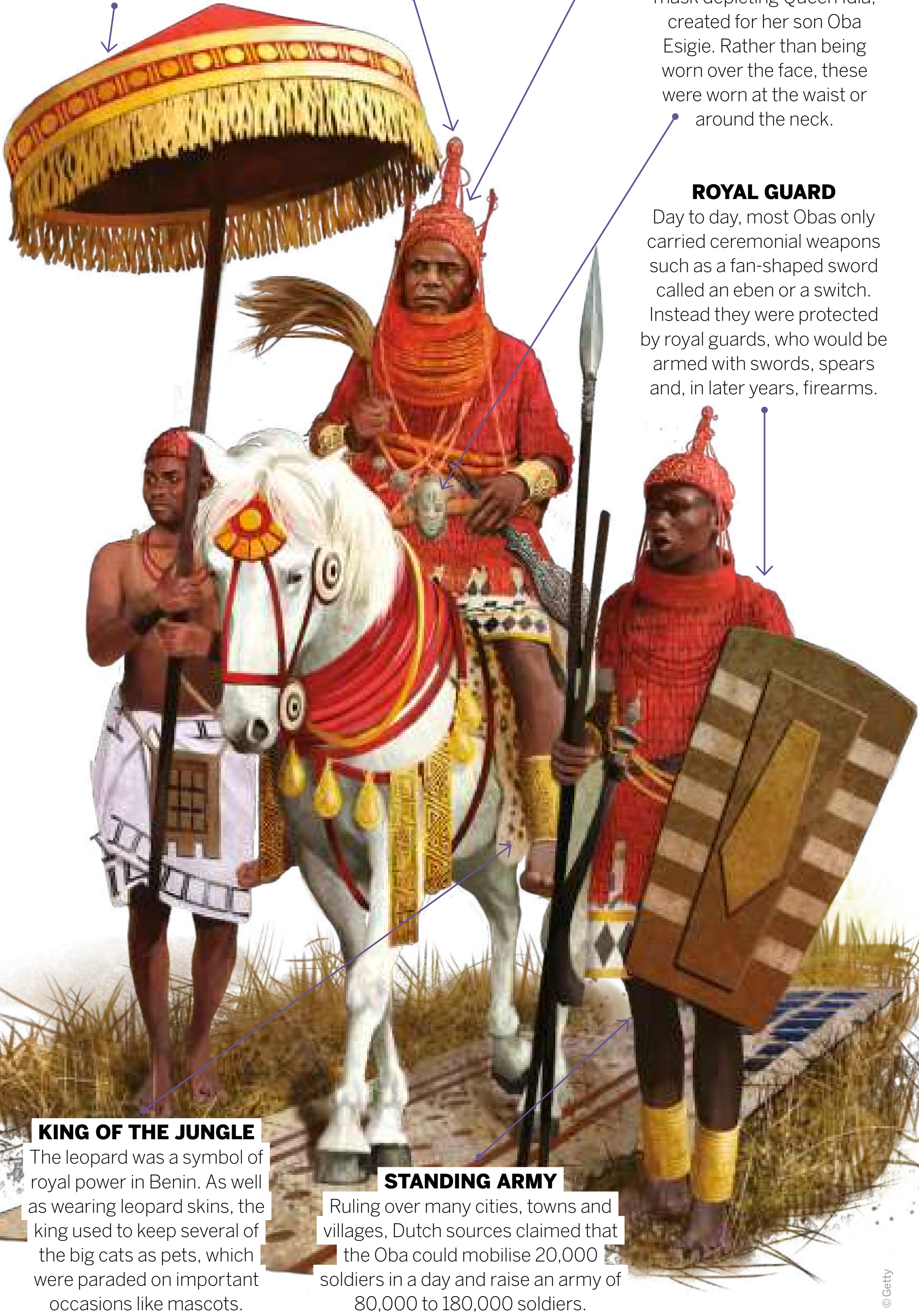
According to the oral history of the Edo people, Benin was originally called Igodomigodo, named after Igodo, founder of the Ogiso dynasty – Ogiso meaning 'rulers of the sky'. Although Igodomigodo would go on to have around 31 Ogiso rulers who governed a formidable kingdom, the Benin Empire didn't begin in earnest until the 12th century. After years of political discord, Igodomigodo sent emissaries to the neighbouring kingdom of Ile-Ife to ask Oduduwa, the father of the Yoruba, for one of his sons to be their ruler. Oduduwa sent his son Oranmiyan, and he became the first Oba, or king. He had a son, Eweka, but Oranmiyan found it hard to rule and he eventually renounced his position, saying that the politics of the people made his leadership intractable.

Oranmiyan called Igodomigodo Ile-Ibinu, or 'land of anger', and left Eweka behind with palace guardians to instruct him in the art and mysteries of the Benin so he could govern his own people. Eweka's eventual reign started the Oba era. Oba Ewedo, who took over after Eweka's death in 1255, changed the name of the kingdom once again, from Ile-Ibinu to Ubini. It was later contact with the Portuguese that changed the name again to Bini, from which we get the name Benin.

With the Oba established, the social hierarchy of the Benin Empire began to take form. Apart from the king, the political elite consisted of the titled chiefs – the Uzama N'Ihinron – and the royal family. The Uzama were powerful, and their role in customs and royal administration was gnomic. There were also the palace chiefs who oversaw palace administration and the town chiefs who carried out regular administrative work such as tribute

THE ALMIGHTY OBA

Benin's political, military and religious leader was an autocratic king



SHELTERED LIFE

The Oba rarely appeared in public, but when he did an attendant would shelter him from the Sun. No one else was allowed to be shaded in this way within the city.

CORAL CROWN

The Oba wore a headdress and tunic woven of red coral beads. While only the king and his closest companions were allowed to wear the beads, they were so rare and valuable – traded from as far away as the Mediterranean – that few others could have afforded them anyway.

GOD-LIKE STATUS

As well as being the highest political authority, Obas were the spiritual leaders of their people. Religious cults would often develop around them and many would even claim to have supernatural powers.

PENDANT MASK

One of the most iconic symbols of the Benin Empire is the finely carved ivory mask depicting Queen Idia, created for her son Oba Esigie. Rather than being worn over the face, these were worn at the waist or around the neck.

ROYAL GUARD

Day to day, most Obas only carried ceremonial weapons such as a fan-shaped sword called an eben or a switch. Instead they were protected by royal guards, who would be armed with swords, spears and, in later years, firearms.

KING OF THE JUNGLE

The leopard was a symbol of royal power in Benin. As well as wearing leopard skins, the king used to keep several of the big cats as pets, which were paraded on important occasions like mascots.

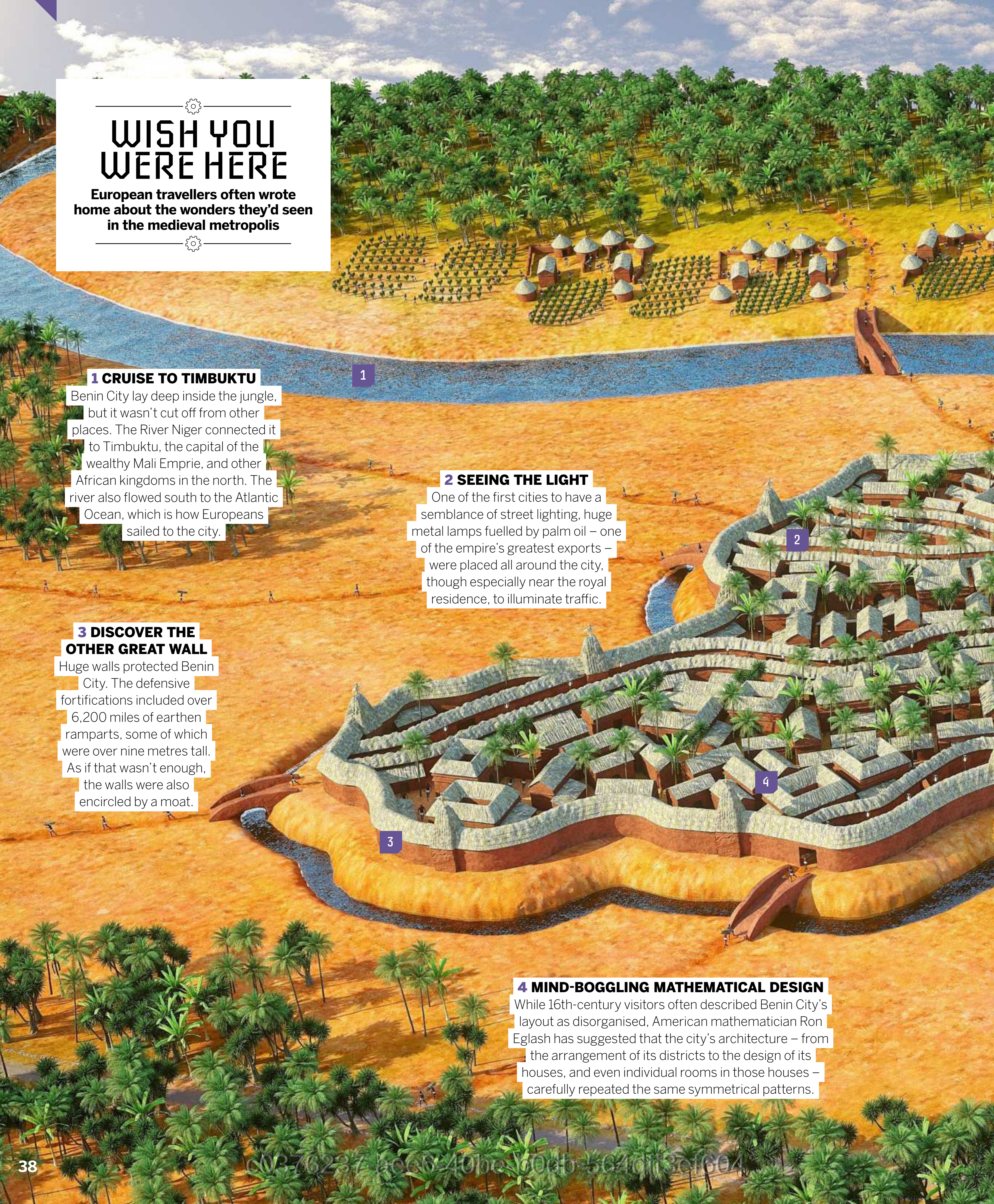
STANDING ARMY

Ruling over many cities, towns and villages, Dutch sources claimed that the Oba could mobilise 20,000 soldiers in a day and raise an army of 80,000 to 180,000 soldiers.

© Getty

WISH YOU WERE HERE

European travellers often wrote home about the wonders they'd seen in the medieval metropolis



1 CRUISE TO TIMBUKTU
Benin City lay deep inside the jungle, but it wasn't cut off from other places. The River Niger connected it to Timbuktu, the capital of the wealthy Mali Emprie, and other African kingdoms in the north. The river also flowed south to the Atlantic Ocean, which is how Europeans sailed to the city.

2 SEEING THE LIGHT
One of the first cities to have a semblance of street lighting, huge metal lamps fuelled by palm oil – one of the empire's greatest exports – were placed all around the city, though especially near the royal residence, to illuminate traffic.

3 DISCOVER THE OTHER GREAT WALL
Huge walls protected Benin City. The defensive fortifications included over 6,200 miles of earthen ramparts, some of which were over nine metres tall. As if that wasn't enough, the walls were also encircled by a moat.

4 MIND-BOGGLING MATHEMATICAL DESIGN
While 16th-century visitors often described Benin City's layout as disorganised, American mathematician Ron Eglash has suggested that the city's architecture – from the arrangement of its districts to the design of its houses, and even individual rooms in those houses – carefully repeated the same symmetrical patterns.

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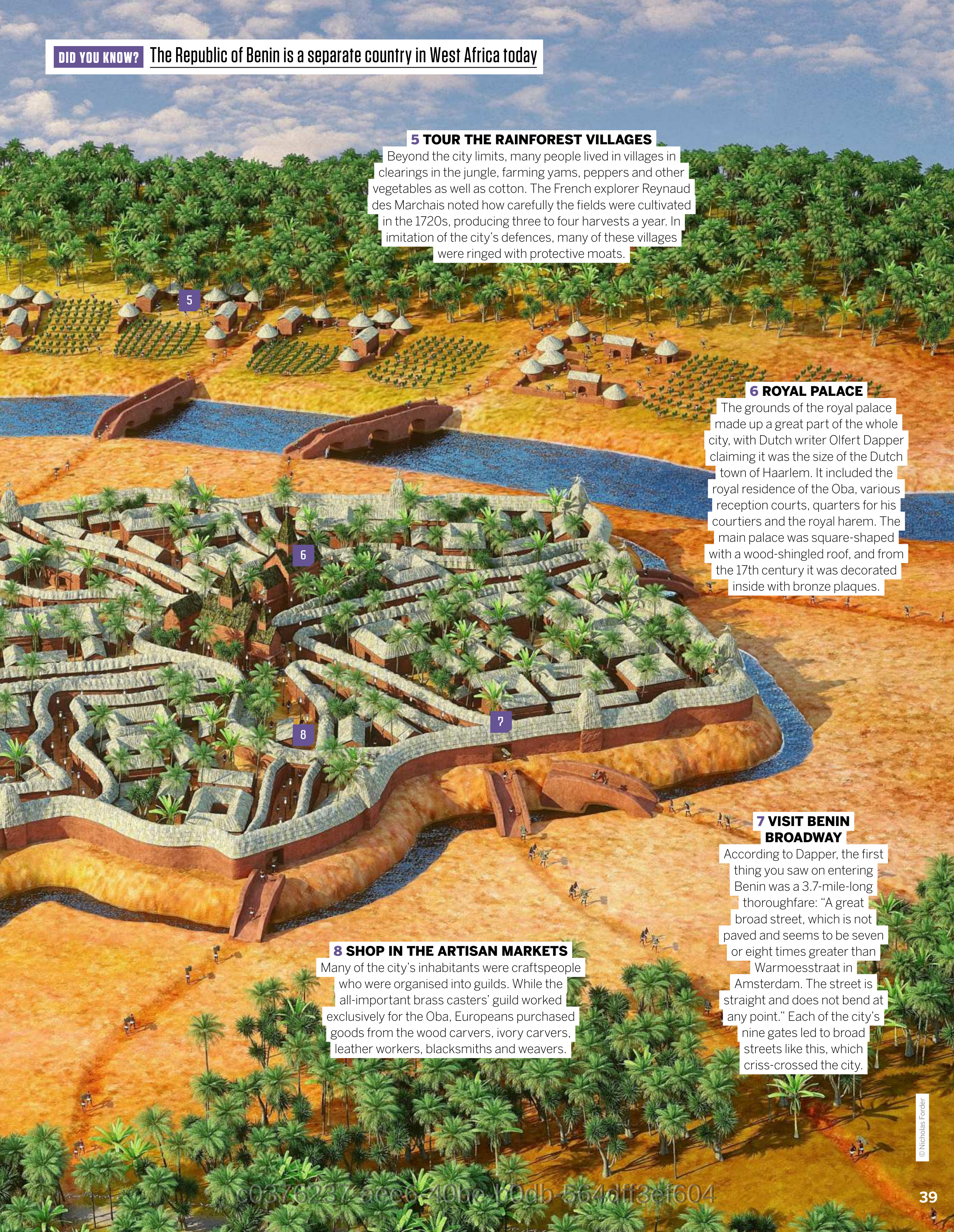
DID YOU KNOW? The Republic of Benin is a separate country in West Africa today



5 TOUR THE RAINFOREST VILLAGES

Beyond the city limits, many people lived in villages in clearings in the jungle, farming yams, peppers and other vegetables as well as cotton. The French explorer Reynaud des Marchais noted how carefully the fields were cultivated in the 1720s, producing three to four harvests a year. In imitation of the city's defences, many of these villages were ringed with protective moats.

6 ROYAL PALACE

The grounds of the royal palace made up a great part of the whole city, with Dutch writer Olfert Dapper claiming it was the size of the Dutch town of Haarlem. It included the royal residence of the Oba, various reception courts, quarters for his courtiers and the royal harem. The main palace was square-shaped with a wood-shingled roof, and from the 17th century it was decorated inside with bronze plaques.

7 VISIT BENIN BROADWAY

According to Dapper, the first thing you saw on entering Benin was a 3.7-mile-long thoroughfare: "A great broad street, which is not paved and seems to be seven or eight times greater than Warmoesstraat in Amsterdam. The street is straight and does not bend at any point." Each of the city's nine gates led to broad streets like this, which criss-crossed the city.

8 SHOP IN THE ARTISAN MARKETS

Many of the city's inhabitants were craftspeople who were organised into guilds. While the all-important brass casters' guild worked exclusively for the Oba, Europeans purchased goods from the wood carvers, ivory carvers, leather workers, blacksmiths and weavers.

© Nicholas Forder

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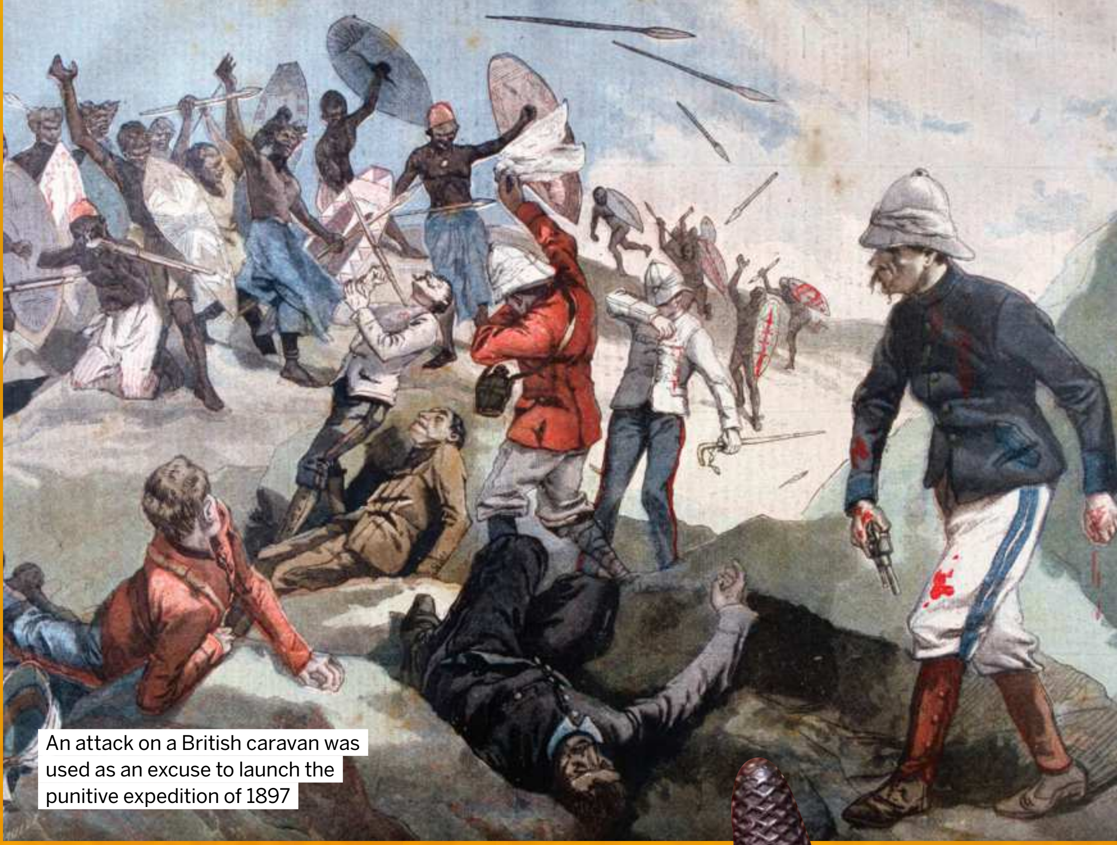
collection and the conscription of soldiers. Other officials carried out various duties that ranged from hunting to astrology, while there were also craftsmen who were like a caste – guilds of artists produced art for the king and his royal court.


An attack on a British caravan was used as an excuse to launch the punitive expedition of 1897

Between the late-13th and the 15th century, the Benin Empire grew sporadically under the expansionist wars of conqueror kings. The fascination with and the formidability of the empire are built around various historical artefacts such as the impressive range of artworks, their advanced trading networks and the military strategies by which the warrior kings expanded and defended Benin. Benin had a large army of well-trained and disciplined soldiers, and the king was the supreme ruling authority over them.

Oba Ewuare I, who reigned between about 1440 and 1473, is largely credited with the transformation of the kingdom into a modern state structure. He reorganised the political structures through reforms that minimised the uneasy relationship between the Oba and the chiefs, and this enabled him to monopolise military power, with the latter factor being responsible for his imperialist expansion. He is also noted for promoting art and artefact production – namely the bronze casting, ivory and wood that Benin would be known for around the world.

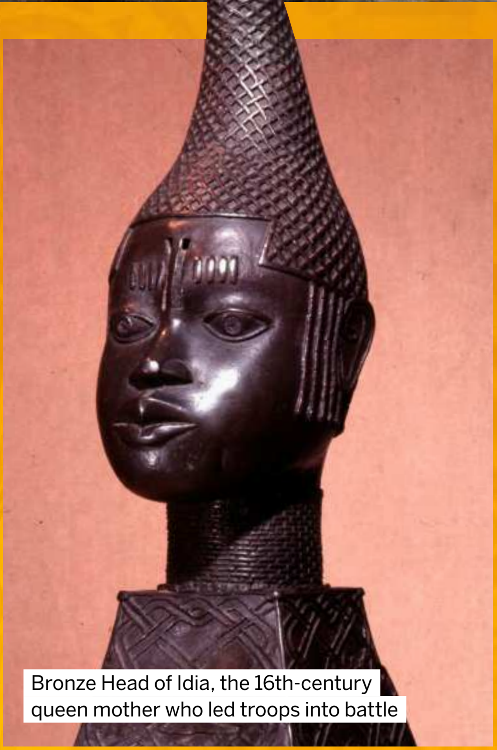
The craftsmen produced a distinct style of art that included heads, figurines, brass plaques and other items of royal adornment. Artistry was used to celebrate royal omnipotence and to legitimise the king's power and glory. As the Oba was believed to embody the country and its continuity, art was used to communicate his divinity and possibly to subjectify his people, who rarely saw or had access to him as he was believed to be a divine being.

Oba Ewuare was also associated with architectural innovation, city planning, grand festivals and the introduction of royal beads. He built on the efforts of Oba Oguola and completed the first and second moats – a network of ramparts that walled the city against external aggressors. The moat was an impressive part of national defence covering roughly 9,940 miles and enclosing 2,500 square miles of community land. It was built over the course of six centuries and it was a work of premechanical engineering marvel. In 1974 *The Guinness Book of World Records* described the Benin Moat as the largest earthwork in the world prior to mechanical inventions, and it's considered to be the largest human-made invention, second only to the Great Wall of China. Oba Oguola was also believed to be the one who first sent his craftsman Igueghae to Ile-Ife to learn the art of bronze casting.

Brass bracelets known as 'manillas' were made in the modern Netherlands, traded throughout West Africa and melted down by bronze workers in Benin

Of the many surviving artworks from the Benin Empire, two are iconic: the Bronze Head of Queen Idia and the Benin ivory mask. The Bronze Head is a dedicatory piece in honour of Queen Idia, the mother of Oba Esigie, the king who reigned in the early 16th century. Queen Idia was the first Iyoba, or Queen Mother, and she played a hugely significant role in his kingship. As Iyoba, Idia was a titled chief in her own right. She had a district, Iyekuselu, where she presided. She could raise the levies necessary to fund the army she oversaw. Although women were typically banned from certain professions – the army included – she went to war and recorded numerous victories. She was described as both possessing military acumen and sorcery, with which she helped her son Esigie defeat his brother Arhuanran, a contender for the throne.

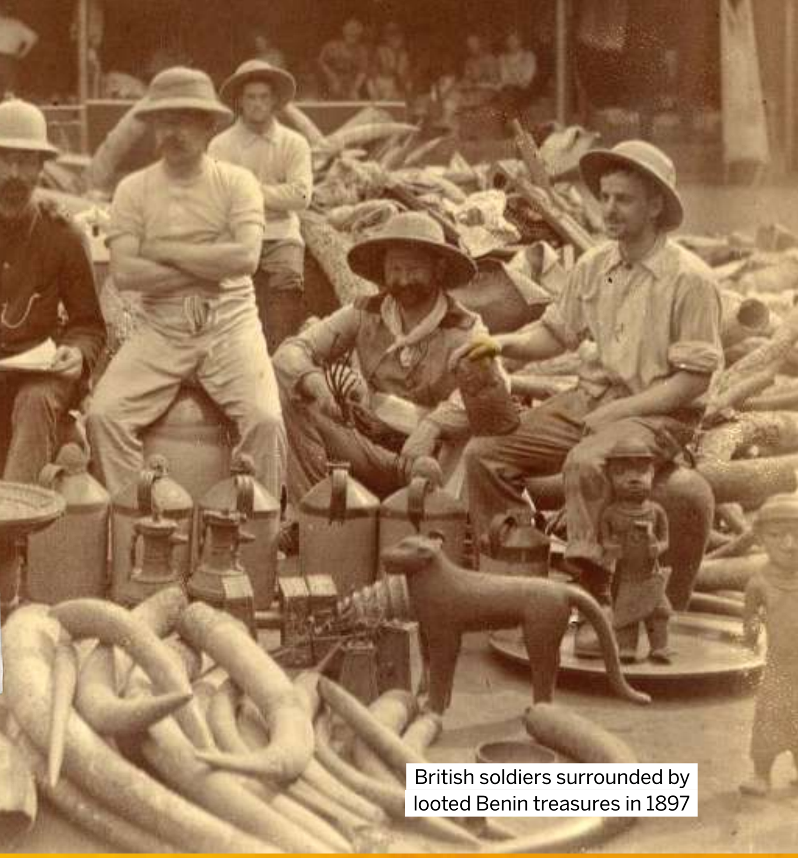
> "She was described as both possessing military acumen and sorcery"


Bronze Head of Idia, the 16th-century queen mother who led troops into battle

As she was the king's mother, the Iyoba already commanded prestige. But Queen Idia also revolutionised the position, allowing future Iyobas to wield actual political power. The position demanded the holder, among other qualities, to possess metaphysical power to help her son overcome other contenders to the throne. Idia was said to have magical healing powers, and she was depicted in many sculptures and artworks commissioned in her honour, such as the Benin ivory mask. This was a small-scale ivory sculpture made in honour of Idia. The mask was worn as a pendant by Esigie.

Today the ivory mask is a stark reminder of the unsavoury circumstances in which artworks left the shores of Africa. The mask was chosen as an emblem of the Second World Black and African Festival of Arts and Culture, a festival that took place in Nigeria and drew people from every part of Africa to celebrate black culture. The Nigerian government tried to secure the mask on

DID YOU KNOW? There have been 40 oba

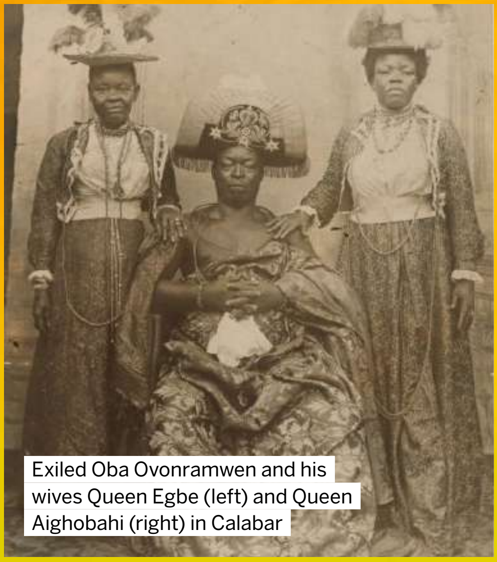

British soldiers surrounded by looted Benin treasures in 1897

The Benin Empire expanded through a mix of trade and conquest

loan from the British Museum, which refused, claiming that it was too fragile to transport. The museum also requested a hefty $3 million as an indemnity. A sign that things might be improving, the British Museum has since held talks to discuss the return of the Benin Bronzes.

Portuguese explorers made contact with Benin in the 15th century, and they quickly started trading. The relationship between Portugal and Benin was so cordial that Oba Esigie was said to have sent ambassadors to Portugal, an exchange that resulted in European influences on Benin's art and culture. Esigie was reputed to have been literate in Portuguese, and this boosted his interactions with the Portuguese traders. Meanwhile, the initial Portuguese missionary effort yielded some fruits, as some churches sprang up in Benin. Trade continued between Portugal and Benin, with items including ivory, pepper and a limited supply of slaves.

During this period, there wasn't really a major drive for a slave trade because it was mainly women who were sold into serfdom in Benin. Those who were enslaved – either because they were captured in war or forced to pay off their debts with hard labour – were arguably held more for the royal court's prestige than actual economic proceeds. Trade in slavery was therefore marginal, as enslaved men were more useful to boost Benin's military might than as a means of exchange. Besides, Benin was enjoying such an economical and military high that it didn't need the proceeds from the Atlantic slave trade. It's also worth noting that Benin's relationship with the Europeans went beyond trading goods to warfare and mercenary services.


Exiled Oba Ovonramwen and his wives Queen Egbe (left) and Queen Aighobahi (right) in Calabar

However, by the 17th century the kingdom had begun to decline as a result of a lack of leadership, internal fractures and indiscipline among members of the ruling class. When the slave trade was abolished and the price of ivory fell, it hit Benin hard. In the mid-18th century the empire got a boost under Oba Eresonyen, but it was not to last. The kingdom was starting to shrink as former territories began to move away from the old empire towards the British, both for trade and protection.

In the mid-19th century, Benin began to trade in palm oil. As the product became more important to the British, they sought to make Benin a protectorate. The Oba took refuge in isolationism, and since Benin's political power had declined, the king took to making human sacrifices to reignite his sacral authority.

In 1892, vice-consul Henry Gallwey pushed Oba Ovonramwen to sign his now-diminished empire over to the British as a protectorate. There was some doubt about whether the Oba indeed signed the treaty, as he was unsure if the British had good intentions. By making Benin a British protectorate, the treaty would have facilitated commerce, ceased slave trading and ended human sacrifice.

Benin eventually fell during the punitive expedition of 1897. The Oba sensed that the British intended to depose him, so his chiefs, against his knowledge, ordered a preemptive attack on a caravan carrying unarmed British officers. Two of the officials managed to escape, but that incident sealed Oba Ovonramwen's fate. Realising that his kingdom would be invaded, he ramped up the rate of human sacrifices to appease his ancestors.

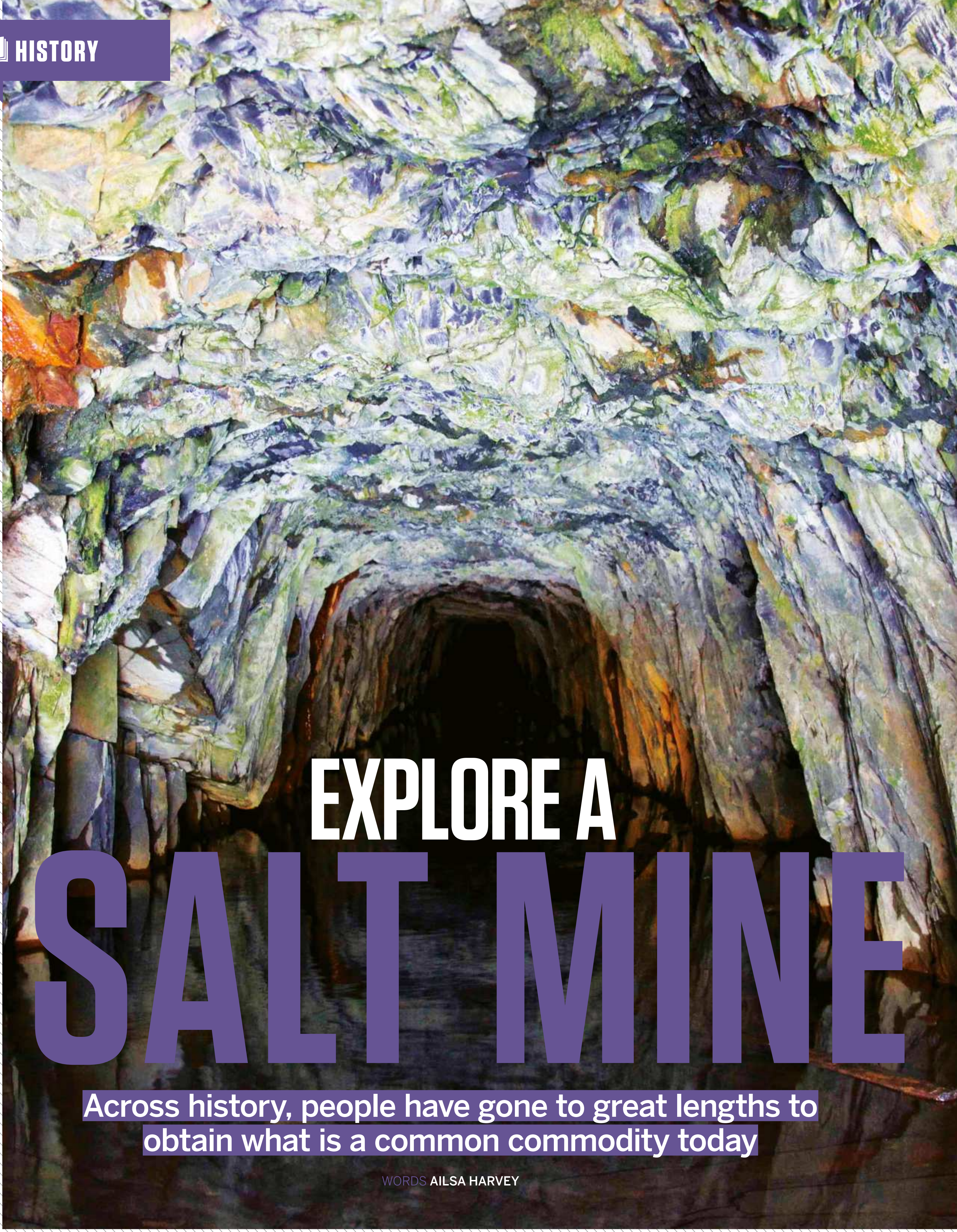
The news of the Oba's increasing bloodthirstiness, coupled with the deaths of the British officials, became a justification for the invasion of 1897, and Britain summoned its forces to descend on Benin. The Oba, his chiefs and their followers fled, although they came back and eventually surrendered. The Oba apparently approached the British with the pomp and pageantry of his position, but he was humiliated and deposed. He was eventually sent to exile in Calabar in the southeastern region of Nigeria, where he died in 1914.

Setting out to destroy what remained, the British set Benin on fire – but they moved the royal treasures to a safe place first. They sold some of the priceless artefacts in Lagos and transferred others to Europe, where they made their ways into private collections and museums. The sales were meant to cover the cost of the expeditions.

In 1914 the throne was restored to Eweka II, Ovonramwen's son, although under the supervision of the British colonial officers. What was left of Benin was nothing but a shadow of its former glory, and today no signs remain of its mighty walls or moats.

An ivory saltcellar showing European traders and their ship from 17th-century Benin

© Getty / Joe Cummings



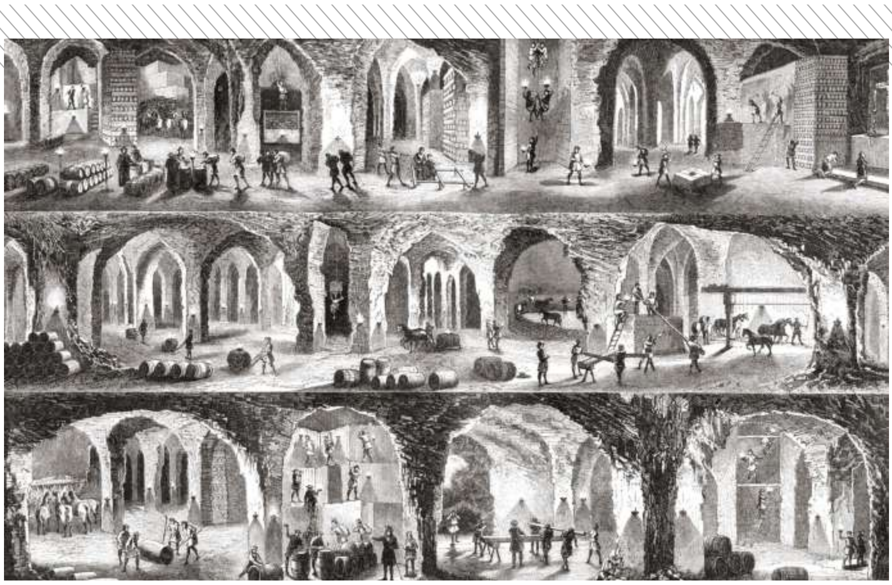
EXPLORE A SALT MINE

Across history, people have gone to great lengths to obtain what is a common commodity today

WORDS AILSA HARVEY

© Getty / Alamy / Wiki: Gordon Leggett

DID YOU KNOW? Salt was given as a religious offering in ancient Egypt to preserve mummies



Humans have collected salt from their surroundings for thousands of years. The oldest method is solar evaporation, which has been practised in warm climates for as long as the Sun has dried up shallow pools of seawater, leaving salt crystals behind. But some of the greatest and most elaborate salt production projects in history involve underground excavation. Rock salt mining is the digging of a maze of tunnels beneath the ground towards large beds of salt that have been buried for millions of years.

Rock salt, also called halite, isn't usually edible. Today, salt from these mines is mostly used for gritting, weed killing, cleaning and water softening. But how does salt form in the rock?

These horizontal salt beds are actually the remnants of ancient oceans. When old oceans dried up, their salt content was left behind in large deposits. Most of the rock salt in Britain was estimated to have been left behind by seawater around 200 million years ago, during the Triassic period. Over the years, other minerals have covered the salt, burying it hundreds of metres underground. Salt mining is a method used to reveal this trapped treasure and bring it to the surface.

Did you know?
The word 'salary' also comes from the Latin word for salt

THE HISTORY OF SALT

Salt has been extracted from mines for 7,000 years as a resource and a means of trade. The mineral was so highly treasured in ancient times that it was referred to as 'white gold'. As early as the Neolithic period, the importance of salt for preserving food made it a valuable commodity. The word 'salad' is derived from the Latin word for salt, 'sal', due to salt being used by the Romans to preserve their leaves and vegetables. After the first simple digging tools were invented, people began to dig 200-metre-deep tunnels to collect more of this life-enhancing salt, which made it simpler to store and preserve food, enhancing early civilisation. Salt collected from below ground in rock is called rock salt. When the first mines opened, the process of extracting salt from mines was very basic and much more strenuous than it is today. With no vehicles or machines, mine workers used shovels and hand picks to chip away at the rock. All salt in early excavations was manually lifted out by hand.

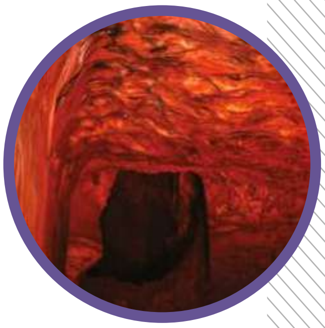
The first method of salt production was to allow shallow pools of salt water to dry in the Sun

5 LARGEST MINES

1 SIFTO
Location: **Canada**
Depth: **600 metres**

Underneath Lake Huron lies the largest salt mine in the world. Its contents were deposited from an ocean that covered the basin of the Great Lakes around 400 million years ago.

2 KHEWRA
Location: **Pakistan**
Depth: **228 metres**



When Alexander the Great was travelling in 326 BCE, he stopped in Khewra. As his horse began to lick the salty ground, this mine was discovered. Around 6 billion tonnes of salt is stored here.

3 SLĂNIC PRAHOVA
Location: **Romania**
Depth: **208 metres**

The largest salt mine in Europe is no longer used for salt extraction. The underground spaces have been converted into galleries that the public can visit for their supposed healing properties.

4 WIELICZKA
Location: **Poland**
Depth: **327 metres**

The Wieliczka Salt Mine was used industrially from the 13th century until 1996. The large mine in the south of Poland has nine levels and is mainly used as a tourist attraction today.

5 ASSE II
Location: **Germany**
Depth: **765 metres**

Between 1906 and 1965, salt and potassium were mined from this site in Wolfenbüttel in Lower Saxony. It was later used for a test to see how well it would store radioactive waste.

LIFE AS A SALT MINER

The Wieliczka Salt Mine opened up seven centuries ago, meaning that many generations of miners have experienced varying conditions as workers underground. Towards the end of the Middle Ages there were around 350 people working in the mine. Salt mining at the site was seasonal until the end of the 15th century, but shortly after became a year-round operation. When the mine was in constant use, job numbers increased massively. Miners needed to do much of the extraction work manually, including digging corridors with pickaxes and carrying the heavy salt blocks on their backs between chambers.

Not all workers were human. From the 16th century until 2002, horses lived at the bottom of the Wieliczka Salt Mine to help people transport salt and materials and to power treadmills. Due to the difficulty of transporting horses through the mine's tunnels, salt mine horses usually spent their entire lives in the darkness of mines. Miners were expected to treat these horses well, and workers who were responsible for their wellbeing gave punishments for animal mistreatment.

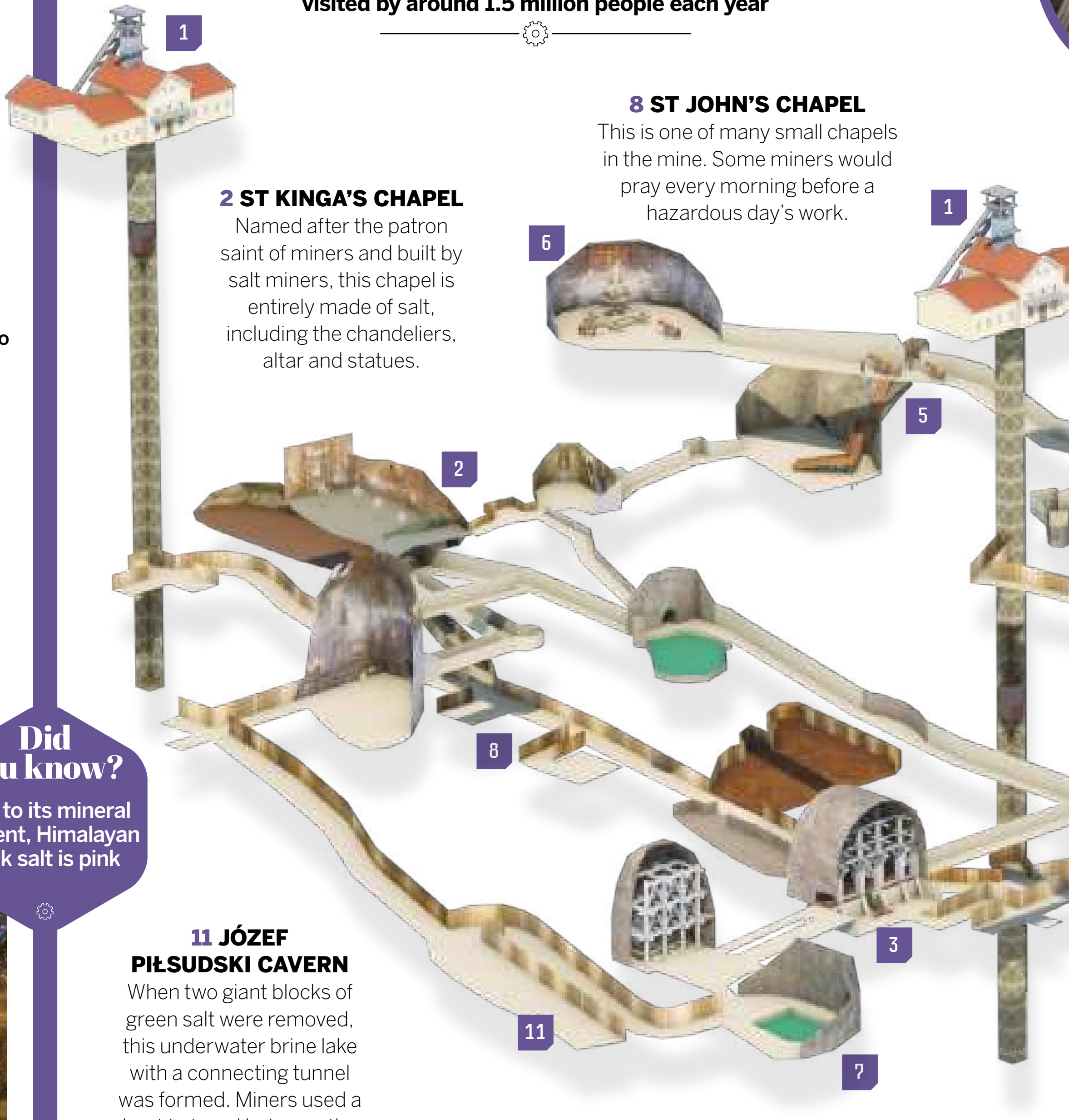
Life-sized figures showing the apparatus used by Wieliczka miners can be seen inside the mine

Did you know?

Due to its mineral content, Himalayan rock salt is pink

INSIDE WIELICZKA SALT MINE

Explore one of the world's oldest accessible salt mines, visited by around 1.5 million people each year



8 ST JOHN'S CHAPEL
This is one of many small chapels in the mine. Some miners would pray every morning before a hazardous day's work.

2 ST KINGA'S CHAPEL
Named after the patron saint of miners and built by salt miners, this chapel is entirely made of salt, including the chandeliers, altar and statues.

11 JÓZEF PIŁSUDSKI CAVERN
When two giant blocks of green salt were removed, this underwater brine lake with a connecting tunnel was formed. Miners used a boat to travel between the two until the drowning of Prussian soldiers in 1915.

7 WEIMAR CHAMBER
In the 1960s this chamber was flooded, producing a lake at the bottom of the mine.

DID YOU KNOW? Some chambers in Wieliczka Salt Mine can fit a hot air balloon – one flew inside for four minutes in 2014

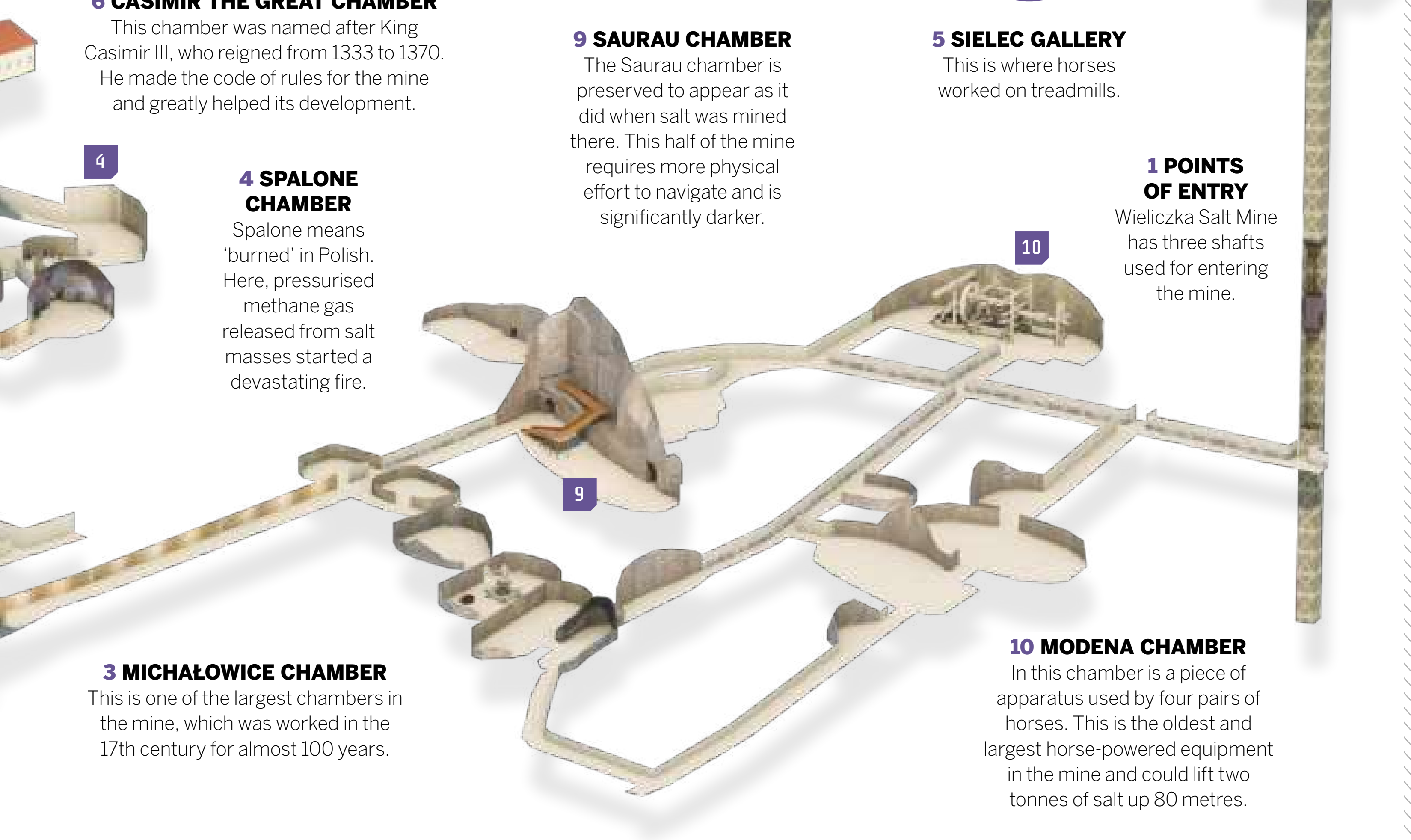
6 CASIMIR THE GREAT CHAMBER
This chamber was named after King Casimir III, who reigned from 1333 to 1370. He made the code of rules for the mine and greatly helped its development.

9 SAURAU CHAMBER
The Saurau chamber is preserved to appear as it did when salt was mined there. This half of the mine requires more physical effort to navigate and is significantly darker.

5 SIELEC GALLERY
This is where horses worked on treadmills.

1 POINTS OF ENTRY
Wieliczka Salt Mine has three shafts used for entering the mine.

4 SPALONE CHAMBER
Spalone means 'burned' in Polish. Here, pressurised methane gas released from salt masses started a devastating fire.



3 MICHAŁOWICE CHAMBER
This is one of the largest chambers in the mine, which was worked in the 17th century for almost 100 years.

10 MODENA CHAMBER
In this chamber is a piece of apparatus used by four pairs of horses. This is the oldest and largest horse-powered equipment in the mine and could lift two tonnes of salt up 80 metres.

HOW ROCK SALT IS MINED

A step-by-step guide to taking salt from rock to surface

1 SHAFT SINKING
Vertical tunnels are pushed downwards through the rock to create pathways about 150 to 600 metres down to the horizontal salt beds. Using tunnel boring machines is often the safest method for this.

2 CREATING ROOMS
Between the mineshafts, the rock is cut with machines and blasted with explosives to create rooms. A horizontal section is cut by an undercutter before small holes are drilled into the newly exposed rock surfaces.

3 EXTRACTING AND CRUSHING
Controlled explosives blast away small portions of the mine's rock, causing a pile of rock salt to fall into the cut 'room'. This is transported to another area of the mine to be crushed into fine salt.

4 TO THE SURFACE
The crushed salt is loaded onto conveyor belts to be lifted to the surface and out of the mine. When at the surface, the salt is filtered and bagged, ready to be sold.

© Alamy / Getty / Illustration by Adrian Mann

DID YOU KNOW? When an object is hidden away, cats can often remember where it is

HOW TO TRAIN YOUR PET

Explore the brains and behaviours of different animals for better pet-human communication

WORDS **AILSA HARVEY**

It's almost every pet owner's dream to get on well with their animal and create a close bond. Each animal will think and process the world around them differently to humans, but by understanding your pet, you'll be able to better communicate, play and even dance together. Starting training with your pet in the early stages is essential for animals such as dogs, who need to learn how to live in the house and later be in public with their owner in a controlled manner. But training doesn't just make life easier for owners.

Studies show that animals that are exposed to regular mental stimulation from their human companions are more confident, trusting and coordinated. Training usually involves different levels of exercise, which is vital for most animals in keeping them fit and healthy while living mostly indoors. It's essential to remember that human concepts and ideas of what is 'right' and 'wrong' behaviour are mostly alien to pets until they are taught. Whether you want to teach your pet the basics or partake in entertaining routines together, patience and persistence are two of the most important qualities you will need to learn.

Did you know?

Dogs are generally about as intelligent as a two-year-old human

The steps of animal training

1

ASSOCIATION

At first, the word of a command will mean nothing to your pet. When first saying the command, demonstrate the action you wish the animal to perform through actions and pointing.

2

CONSISTENCY

If there's more than one person living in your house, make sure you use commands and actions that match. A pet needs to receive the same information and expectations from everyone to learn quickly.

3

REPETITION

Your pet won't instantly catch on to different tricks and commands. Keep repeating the command until the word is ingrained and associated with the relevant action.

4

REINFORCEMENT

Try using an action that matches each command, such as tapping the back of a pet's body while saying "sit". This will serve as another prompt for each action to make the association stronger. When successfully achieved – with or without the prompt – reward with a treat.

5

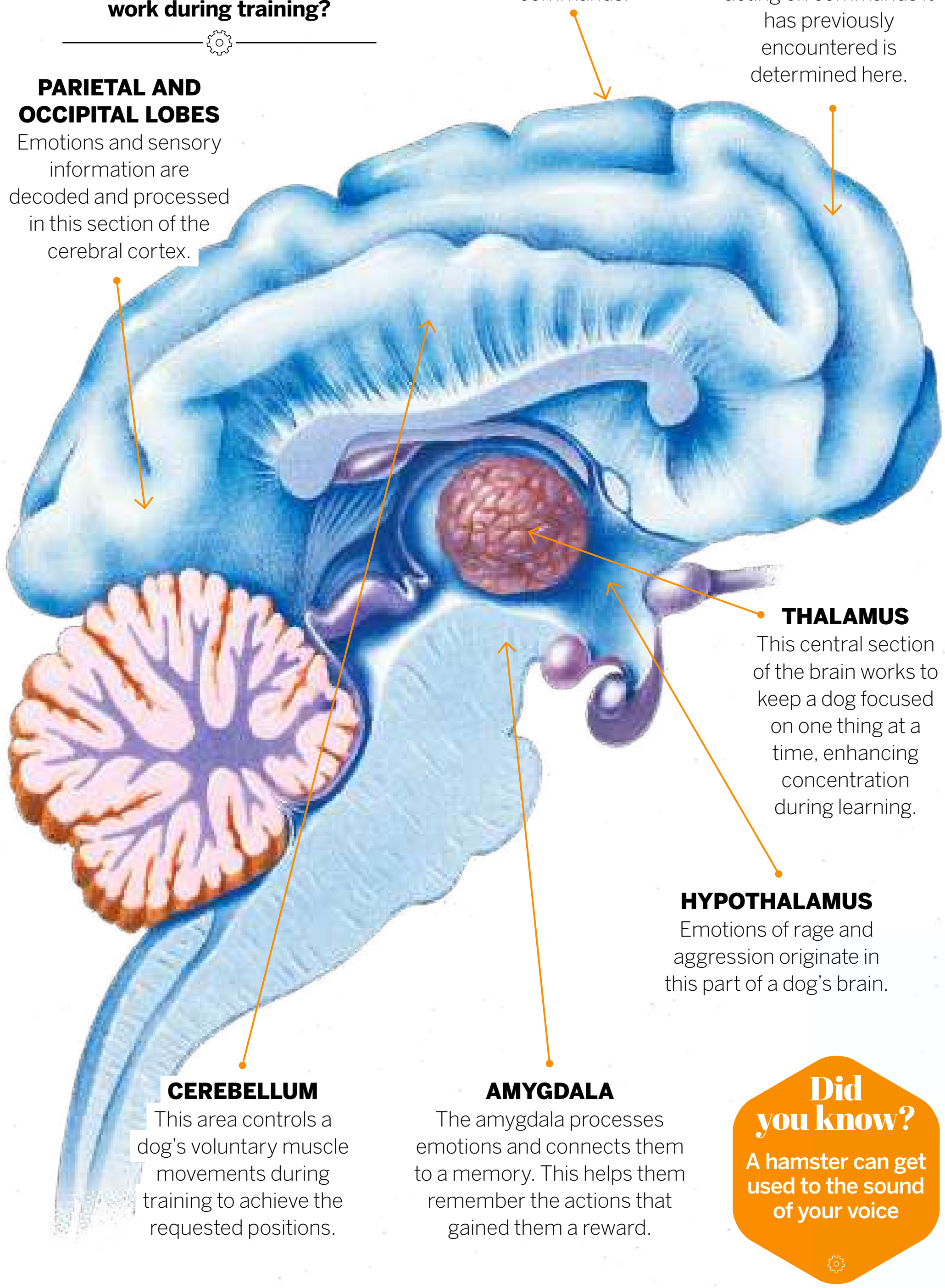
MAINTENANCE

When you have achieved the desired level of training for your pet, maintain constant practice. Test their abilities daily if possible so that they don't forget over time.

© Getty

THE BIOLOGY OF OBEDIENCE

How do different parts of a canine brain work during training?



CEREBRAL CORTEX
The main part of a dog's brain receives sensory information such as visual and audible commands.

FRONTAL LOBE
A dog's alertness and intelligence is controlled in this area. Its memory for recognising and acting on commands it has previously encountered is determined here.

PARIETAL AND OCCIPITAL LOBES
Emotions and sensory information are decoded and processed in this section of the cerebral cortex.

THALAMUS
This central section of the brain works to keep a dog focused on one thing at a time, enhancing concentration during learning.

HYPOTHALAMUS
Emotions of rage and aggression originate in this part of a dog's brain.

CEREBELLUM
This area controls a dog's voluntary muscle movements during training to achieve the requested positions.

AMYGDALA
The amygdala processes emotions and connects them to a memory. This helps them remember the actions that gained them a reward.

Cats are often more independent than dogs

DOGS VS CATS

If you've ever tried to train both a cat and a dog, you're likely to have found the latter an easier task. But why is it that dogs will usually sit, while cats do as they please? In the wild, dogs are much more used to living in groups, and use their pack mentality instincts to adapt well to human commands. While dogs are naturally inclined to follow a leader, cats are more likely to act upon their own desires, regardless of what is suggested to them. However, cats do hold one great advantage in house training, as they are quick to associate litter trays as a place to go to the toilet. Dogs have 530 million nerve cells in the brain's cerebral cortex, whereas cats only have 250 million. This enables dogs to process more complex thought patterns and words, ultimately making them easier to train. Cats have tiny hairs in their ears that make them better listeners than dogs, but due to their desire to be accepted into a family, or pack, dogs are more likely to act on the commands they hear.

Did you know?

A hamster can get used to the sound of your voice

Soundboard buttons can be pressed to produce the words pets can't say

CAN PETS TALK?

Online videos of animals communicating with words are going viral. Videos show cats and dogs pressing buttons on a soundboard while their owners reply to them. The pets have a range of buttons they can press to play an audio recording of human speech. Each button plays a different word and requires owners to train their pet to associate the sounds with their meanings. One dog owner who has achieved a great deal of success with this is Alexis Devine, a user on the social media platform Tik Tok. She asks her dog Bunny questions, who responds with buttons. While these won't be full sentences, the combination of words makes it clear what the sheepadoodle is asking for, such as "more, food, now". There's even a video showing Bunny looking in the mirror before running to the buttons and pressing "who's this". After seeing the videos, scientists at the Comparative Cognition Lab at the University of California, San Diego have begun research, studying dogs, cats and horses to learn more about the capabilities of our pets' brains.

DID YOU KNOW? Dogs with ‘retriever’ in their name were originally bred and trained to fetch animals

BREED COMPARISON

Which dog breeds are typically the easiest or hardest to train?

Training champs

BORDER COLLIE

INTELLIGENCE

This breed usually has relatively high energy and likes to be kept busy. Their high intelligence also means that they are quick to learn what is expected of them.

POODLE

OBEDIENCE

Poodles can begin to obey commands at just six weeks old. While their fluffy appearance is often what is first noticed about the breed, their looks are paired with natural athletic ability.

GERMAN SHEPHERD

LOYALTY

These dogs are some of the most willing to learn. For this reason they are often put to work as police dogs.

Struggling students

BEAGLE

CURIOSITY

Beagles will explore everywhere, both in the home and out and about. This can make it difficult when training, as they can get easily distracted.

SIBERIAN HUSKY

ACTIVE

This breed needs regular long periods of exercise, as they were bred for endurance to pull sleds. They are known to be more mischievous if they are left too long and get bored.

CHINESE SHAR-PEI

TERRITORIAL

Families with children are discouraged from choosing this breed as they can be more unfriendly towards people than other breeds. This makes training a challenge – trainers are more likely to be seen as a threat.

CHINESE SHAR-PEI
POODLE
SIBERIAN HUSKY
BORDER COLLIE
BEAGLE
GERMAN SHEPHERD

5

PET RECORD BREAKERS

1 HAMSTER ATHLETE
FASTEST HAMSTER RACER

Every year, a competitive hamster sport called hamster racing takes place. The pets are placed in specially made vehicles with a hamster wheel at one end. In 2001 the world record was set by the winner, covering the nine-metre course in just 38 seconds.

2 CAT TRICKSTER
MOST TRICKS IN A MINUTE

Although cats are harder to train than dogs, it’s still achievable. Cat owner Anika Moritz from Austria showed this in 2021 when she and her cat broke the record for the most tricks performed in one minute. They managed to demonstrate 26 different skills.

3 RABBIT BALLER
MOST BASKETBALLS DUNKED

Bini the bunny rabbit, from Long Beach, California, holds the world record for the most basketball hoops scored in one minute. The rabbit is trained to pick up small basketballs in its mouth and release them through a miniature basketball hoop. Bini managed to dunk seven successive baskets in 2016, gaining the record.

4 CHATTY BIRD
LARGEST VOCABULARY

Speaking a total of 1,728 different words, the world record for the bird with the largest vocabulary belongs to Puck, a budgie from California. This skill was demonstrated in 1995.

5 SKATEBOARDING DOG
LONGEST RIDE THROUGH A HUMAN TUNNEL

Otto the bulldog was trained to skateboard through the legs of 30 people in a row to become the best skating dog in the world. Otto is from Lima, Peru, and wasn’t led or touched during the skateboard ride.

© Getty / Science Photo Library

HAMSTER HANDLING

These top tips will help you learn the best ways to tame your hamster

PLACEMENT IMPORTANCE

For different tricks, you need to know what will help your pet perform an action. To teach a hamster to stand, place the treat directly above them.

GETTING CLOSE

Before a hamster will follow your hand, it needs to be comfortable with it. Before performing tricks, place your hand gently and still on the cage floor to give your pet time to explore you first and get used to being close.

TREAT CHOICE

Nutritious treats such as seeds, fruits and vegetables are best for your hamster. Only give treats when it's earned, as it will become less of a treat the more that it's provided.

AWAKE AND READY

Don't wake your hamster up to train; try training in the late afternoon and evening when they are naturally awake. These sessions should be short.

STAND

Wait until the hamster has performed the trick before saying the command. When the hamster is on two feet, say stand, so that this position is associated with the word.

Did you know?

Hamster racing is streamed live online

Syrian hamster: five training traits

What makes this type of hamster the most tame?

1

LARGE SIZE

Being one of the bigger hamster species, Syrian hamsters are less skittish than others.

2

SOLITARY

Hamsters are usually solitary, but they often enjoy the affection from humans that they don't receive from other hamsters.

3

CURIOUS

A Syrian hamster's ears are often upright to keep them alert, and they constantly explore their surroundings.

4

ATTACHMENT

Syrian hamsters like attention. When they gain your trust, they can actively seek attention from you.

5

ACTIVE

As active animals, Syrian hamsters need lots of exercise. This means that the exertion required for light training isn't too much for them.

ANIMALS WITH JOBS

This image shows a dolphin during military training

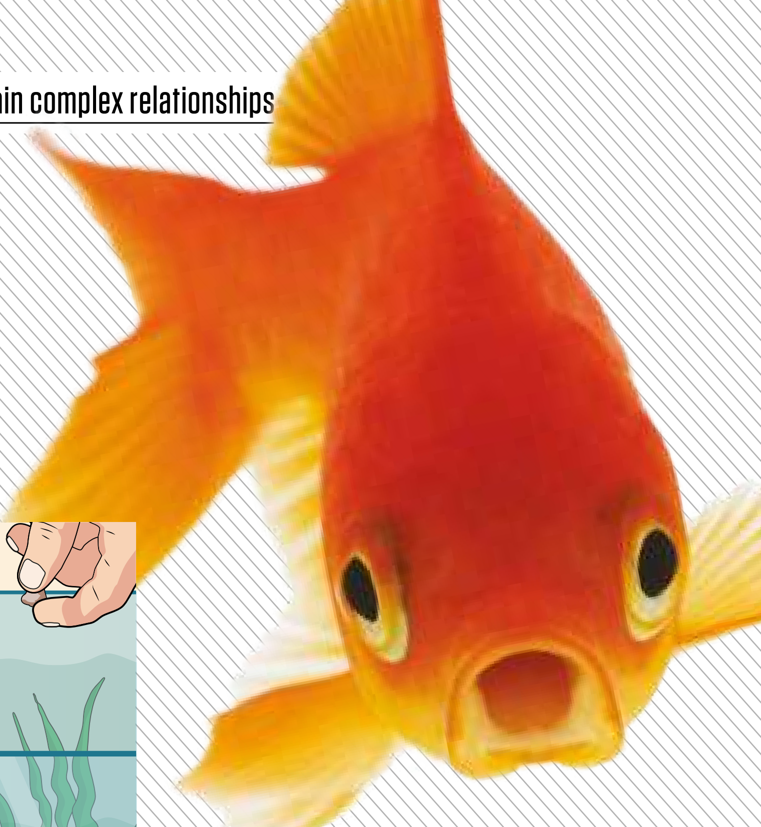
Some animals have been successfully trained to levels high enough to secure them a job. These jobs greatly benefit diverse groups of people on a daily basis. Service dogs, for example, are trained specially to suit the needs of those they will accompany. This includes guide dogs trained to navigate the world for blind people and keep them safe, service dogs who know to guard their owner when they experience seizures or dogs who are trained to distinguish between sounds and alert their deaf owners.

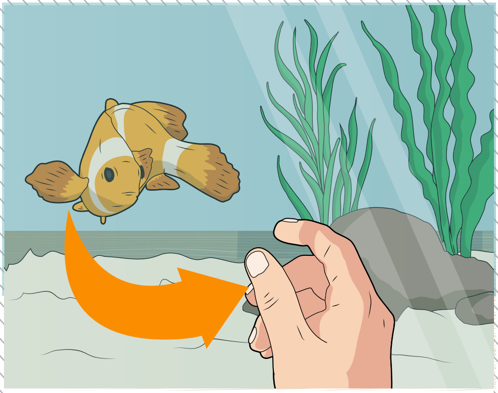
Many animals learn niche skills for work in the military. Dolphins have proved trainable, using their underwater echolocation skills to seek out mines in the dark depths of the ocean. When it signals that it has spotted a mine, the dolphin is given a buoy that it places at the location for future reference and investigation.

DID YOU KNOW? Fish have good memories that allow them to develop and maintain complex relationships

FISH TRICKS

Learn how to perform these impressive tank aquabatics with your fish

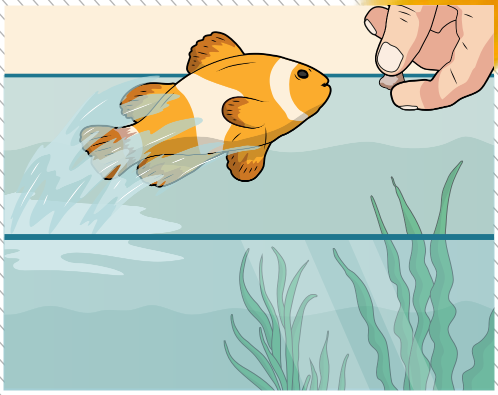




1

FINGER FOLLOWING

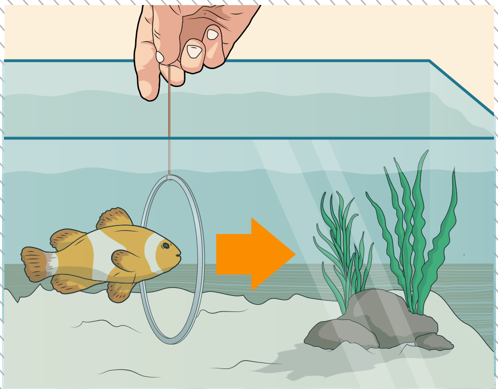
The first step of any trick is to get the attention of your pet – in this case placing your finger in their eyeline on the outside of the tank will work. If the fish appears not to notice it, move your finger about. As soon as it acknowledges your finger, reward the fish with food instantly. Once it comes back to your finger, use the same technique while moving your finger along the tank. As soon as it successfully follows the finger, give the fish some food.



2

AIR JUMP

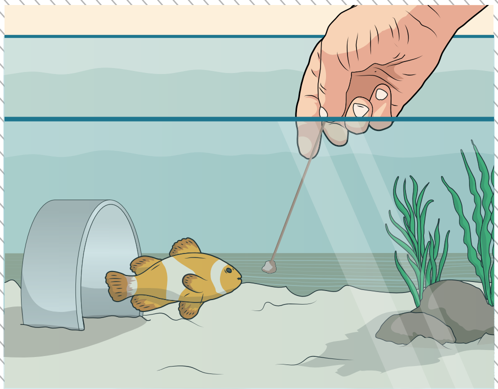
Before attempting this trick, try feeding your fish by hand inside the tank so it will learn to trust your hand. Once your fish clearly makes this association, begin testing out a jump. Hold the food above the water instead of in the water until the fish notices. Place your fingers at the surface of the water, and when the fish swims close, pull up your hand away from it. Only when the fish successfully follows the food up into the air should you award it with food.



3

SWIM THROUGH HOOPS

Using a clean hoop that's wide enough for your fish to fit through, tie a fresh piece of string to the top of it and dangle the hoop into the water. Make sure you are holding the hoop side-on to the edge of the glass and use the finger following trick to guide the fish through the hoop. After multiple successes, you can create hoop obstacle courses and introduce smaller and more challenging targets for your fish to swim through.



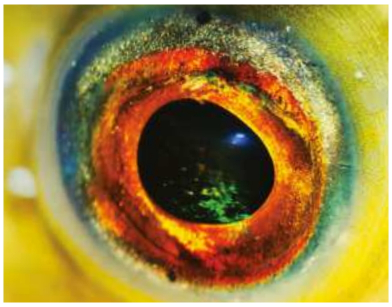
4

OBSTACLE COURSE

If you think you've mastered single tricks, why not combine them? This can only be done when your fish has tried other tricks and knows its efforts will be rewarded. Using hoops, arches and other tank decorations, create an interesting course at the bottom of the tank. Instead of using a finger, attach a piece of food to the end of a stick and guide your fish along the route. If it only manages part of the course, start with a smaller one and work your way up to the full routine.

FISH TRAINING BIOLOGY

For you and your fish to become the perfect training duo, you need to understand how your pet sees and explores its surroundings. A fish is more likely to succeed in training if you use clearly visible targets. Fish can see colour, so you should use targets in a variety of different colours that stand out against your fish's tank environment. However, you can help your pet know where these targets are by keeping in mind how fish sense the world in other ways. Fish have an organ called the lateral line, which makes them very sensitive to sounds and vibrations in the water. When you have set a target, you might want to clap your hands near the target just before training. This not only alerts the fish to where you are, but also helps them associate a particular sound with training time.



A fish's eye has a wide field of view

© Getty / Illustration by Ed Crooks

WHAT IS PLUTONIUM?

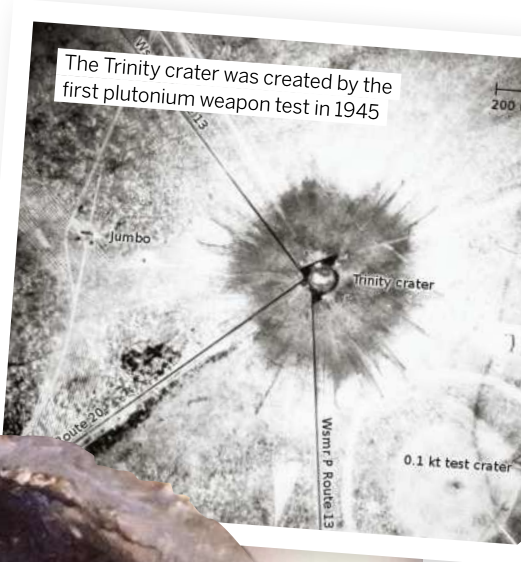
The 94th element in the periodic table is one of the most dangerous on the planet

WORDS **LAURA MEARS**

Plutonium is radioactive, but it doesn't seem that harmful at first glance. It looks like any other metal, with a silvery sheen that turns dull in contact with the air. Queen Elizabeth II held a piece during a visit to Britain's Atomic Energy Research Establishment at Harwell in 1957. It was warm to the touch, but it didn't hurt. Even eating it doesn't really do any harm, although it's definitely not recommended. Plutonium atoms fall apart by a process called alpha decay. They release particles made from two neutrons and two protons – essentially a helium nucleus. They're so bulky that they can't pass through human skin. Left to its own devices, plutonium decays slowly. The real danger comes when humans interfere.

An isotope of plutonium named plutonium-239 is fissile, which means it can start a nuclear chain reaction. The United Nations lists it as one of only two radioactive isotopes used to make atomic bombs. When you hit a plutonium-239 atom with a neutron, more neutrons will spill out. When those neutrons hit other plutonium-239 atoms, the same thing happens again... and again and again. This releases an enormous amount of energy. Under the right conditions, the energy from nuclear fission can be harnessed for good. The heat released can boil water to make steam, which can spin turbines. A third of the energy made by nuclear power plants comes from plutonium. But it can also be used as a weapon. In 1945, the United States developed a bomb containing a small sphere of plutonium and then used it to devastate the Japanese city of Nagasaki.

The International Panel on Fissile Materials estimates that there are now 140 tonnes of weapons-grade plutonium worldwide. It forms part of the so-called 'nuclear deterrent' in countries like the US, the UK and Russia. You only need a bowling-ball-sized amount of plutonium to make a pit – the core of an atom bomb. But getting your hands on the raw materials isn't easy. Plutonium doesn't really exist in nature; it only comes from nuclear reactors. There's one place in Africa – Oklo in Gabon – where conditions were just right for the element to form naturally, but most plutonium is completely human made.


The Trinity crater was created by the first plutonium weapon test in 1945

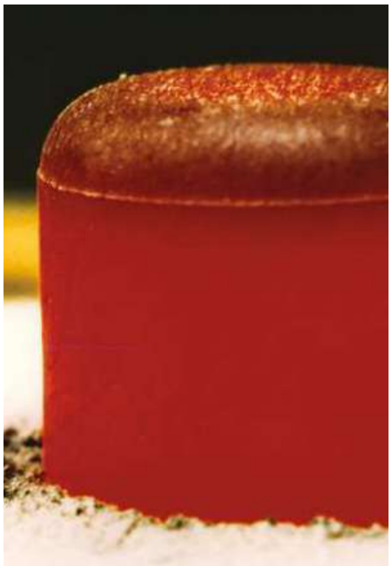
This is a ring of weapons-grade plutonium made at Los Alamos National Laboratory

Did you know?

Plutonium is one of the 15 actinide elements

PLUTONIUM POWER

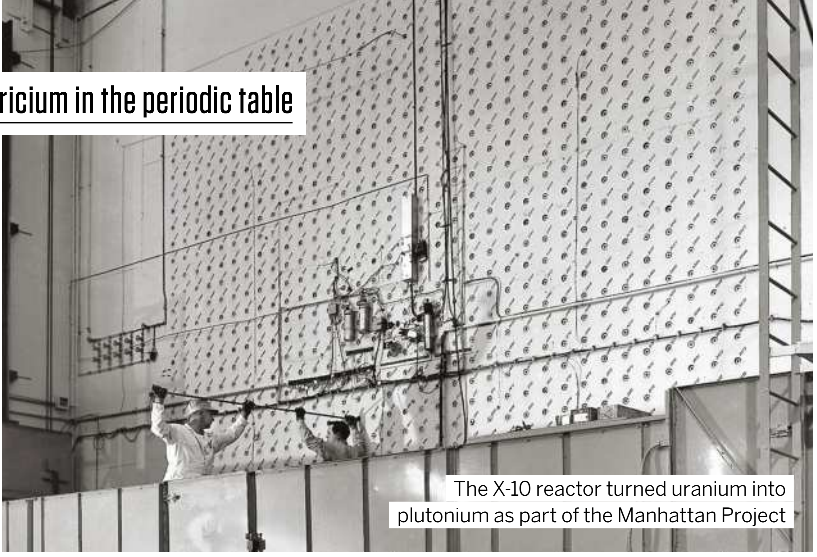
A radioisotope thermoelectric generator (RTG) is a nuclear battery. It captures the heat from decaying plutonium and turns it into electricity using wires called thermocouples. When one end of a thermocouple gets hot, a current starts to flow. RTGs are used to bring power to remote places, from lighthouses on hazardous coastlines to probes in space. But you can't use any old radioactive element to make them. NASA has a strict list of criteria for nuclear batteries. The fuel must be safe in case of a launch accident. It mustn't release too much beta, gamma or neutron radiation because they interfere with equipment. It must be stable, as you don't want it to explode. It must have a long half-life, since you can't change a battery in space. And it must be light, because it needs to get off the launchpad. Of the 2,900 known radioactive isotopes, plutonium-238 is one of just 22 suitable for the job.


The heat from this glowing pellet of plutonium oxide can power a spacecraft

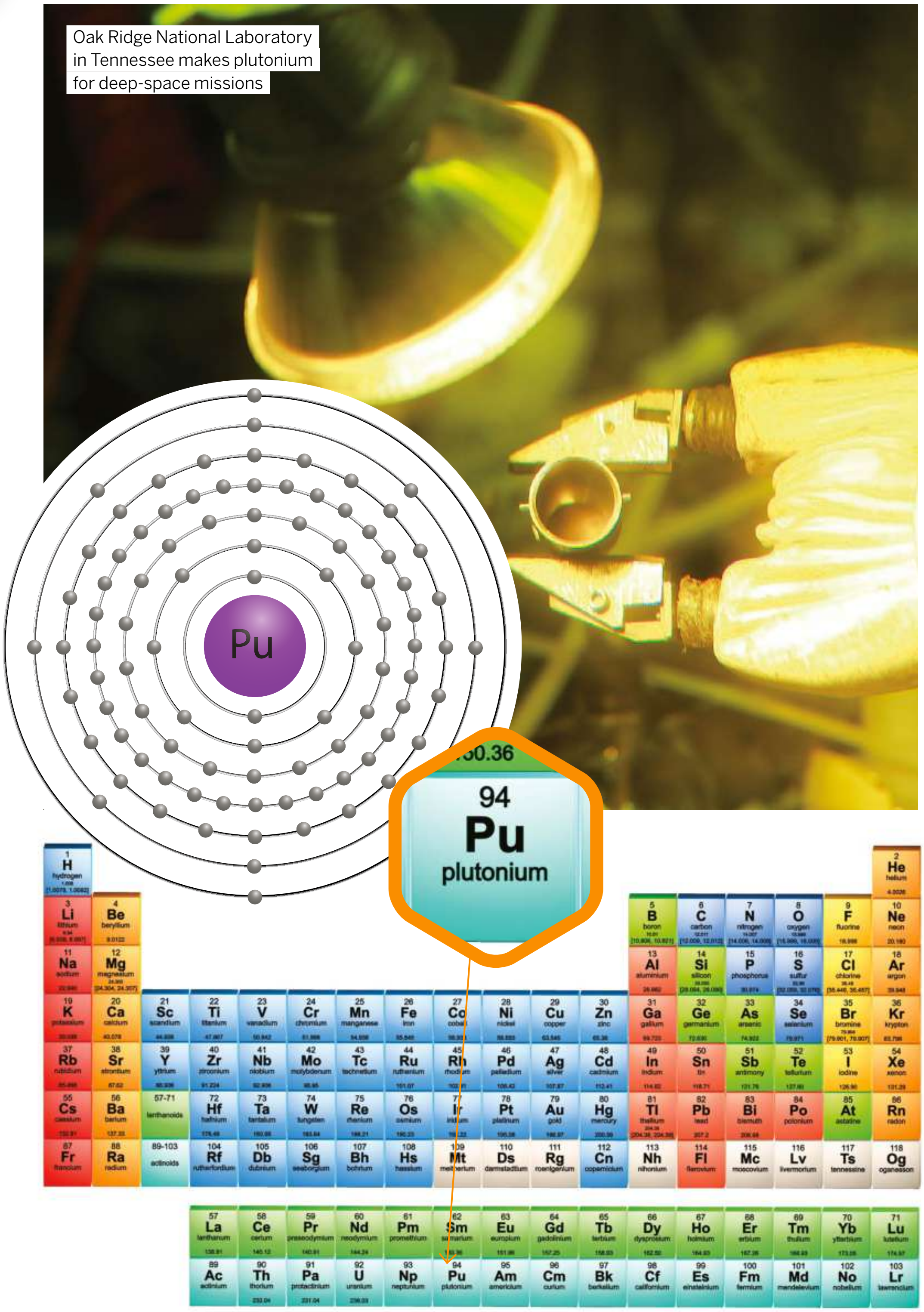
DID YOU KNOW? Plutonium comes after neptunium and before americium in the periodic table

THE DISCOVERY OF PLUTONIUM

Plutonium is a relatively new addition to the periodic table. It was first encountered during World War II. In 1940, scientists at the Berkeley Radiation Laboratory were experimenting with uranium, firing heavy hydrogen atoms at the element to see what would happen. Uranium is radioactive, and the bombardment caused it to split apart, releasing another radioactive element, neptunium. That element was unstable, and it decayed into yet another unknown radioactive element. Following the planetary theme, the scientists called it plutonium. Its potential as a nuclear weapon was immediately evident, and within two years top-secret plutonium production had started at the Metallurgical Laboratory in Chicago.



The X-10 reactor turned uranium into plutonium as part of the Manhattan Project



Oak Ridge National Laboratory in Tennessee makes plutonium for deep-space missions

USES FOR PLUTONIUM

1 NUCLEAR WEAPONS
Just one kilogram of plutonium can produce a blast equivalent to 10,000 tonnes of chemical explosives. Nuclear treaties aim to prevent the use of these devastating weapons.

2 SPACE HEATERS
The electrical components on spacecraft operate best at certain temperatures. Plutonium-238 releases a lot of heat when it decays, helping warm up these delicate instruments in deep space.

3 THERMAL ENERGY
The heat generated by decaying plutonium can be captured and turned into electricity. One kilogram of plutonium can produce 8 million kilowatt hours of electricity, making it very efficient, and with no direct carbon dioxide emissions.

4 NUCLEAR PACEMAKERS
A handful of people in the United States have plutonium-powered pacemakers. These devices aren't dangerous inside the body, but Los Alamos National Laboratory disposes of them carefully when they're removed.

MEDTRONIC
LAURENS-ALCATEL
MODEL 9000
RADIOACTIVE

© Getty / Alamy / Los Alamos National Laboratory / U.S. Department of Defense / United States Department of Energy / Oak Ridge National Laboratory / wiki: Hansueli Krapf

VOCAL CORDS EXPLAINED

How the folds within your voice box give you the ability to shout, talk and sing

WORDS **JAMES HORTON**

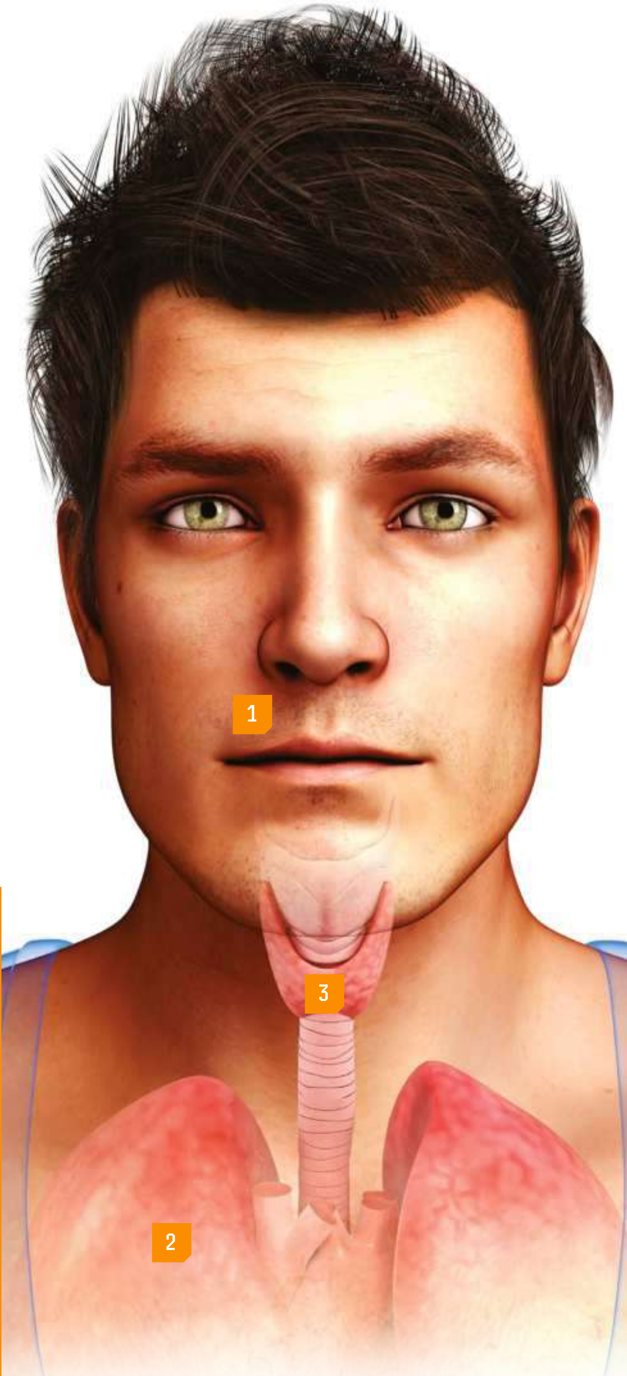
The power to generate sounds and form words is one of humankind's most important assets. Without speech we simply wouldn't have been able to build the world we live in today. Our power of voice comes from three interacting systems: airflow from the lungs, vibration from the voice box and resonance from the head and neck. At the centre of these systems, nestled within the voice box, are the vocal cords. The vocal cords, or vocal folds, are the origin of sound, generating the vibrations that are later refined into a plethora of nuanced noises. The vocal cords consist of two main muscular folds of tissue. These are attached to either side of the cavity air travels through as it goes to and from the lungs, known as the glottis. Using intrinsic muscles, the vocal folds can be stretched, shortened, retracted from and used to cover the glottis. All these actions work to generate different vibrations and sounds.

Humans share the same basic structure of vocal cords, and yet we don't all sound the same when we sing. Instead our voices change depending on age, sex and the individual. When we're young, our vocal folds are small and thin. This means that when the folds vibrate, they do so quickly, generating a high pitch. However, as we go through puberty hormones drive our larynx to grow and the vocal cords grow longer and thicker. The thickening causes the folds to vibrate more slowly, generating a lower pitch. The growth during puberty is more pronounced in males, which is why men typically have lower voices than women. However, even among the same age and sex profiles our voices vary considerably. This is due to the numerous shapes, sizes and strengths of muscles, bones and cartilage found in our voice box, neck and head, which together shape the sound and resonance of our individual voice.

SECONDARY ROLES

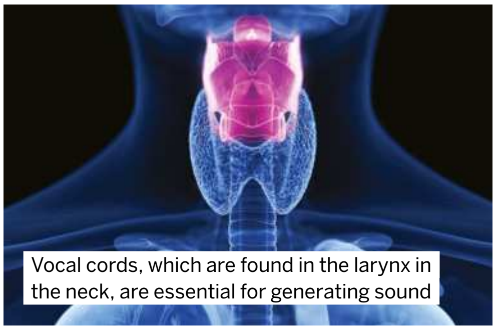
As well as generating sound, the vocal folds' position of being able to cover and uncover the glottis makes them gatekeepers to the airways of the lungs. As a result they have several secondary roles relating to the airways. As we swallow, the epiglottis moves to cover access to the larynx, preventing food and drink from entering the lungs, and the vocal folds also close to help prevent choking. When we cough, the folds first close the glottis so that pressure can build in the lungs, then open to allow the air to be forcefully released.

Vocal folds are involved in coughing; they control the collection and release of air



1 SOUNDS TO WORDS
Sounds from the larynx are turned into speech by the bones and muscles of our head and neck.

2 AIRWAYS
The voice box, or larynx, sits above the lungs and relies on the flow of air to generate sounds.



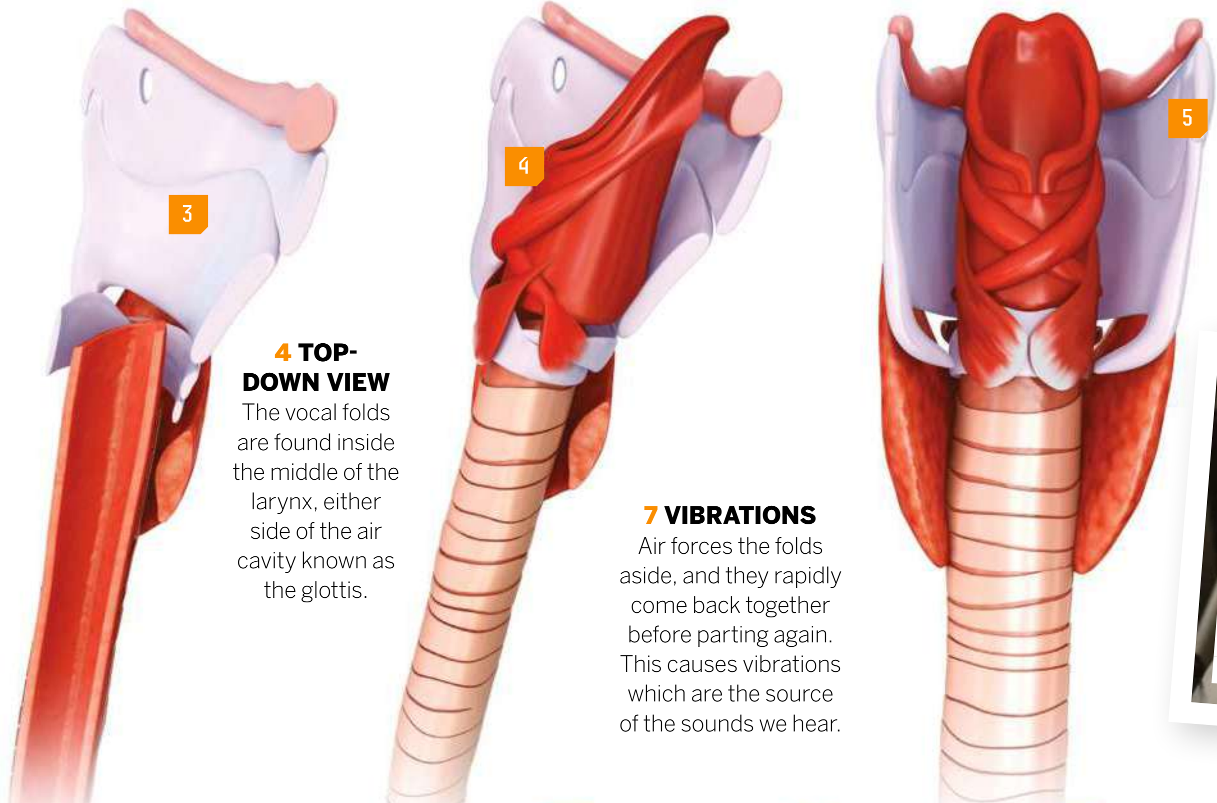
Vocal cords, which are found in the larynx in the neck, are essential for generating sound

Smoking can irritate the vocal cords and significantly change the pitch of your voice

DID YOU KNOW? The larynx also has 'false' vocal folds that sit above the 'true' vocal folds – these help with speech

HOW WE MAKE SOUNDS

Humans employ flexible curtains of muscle to make the sounds we then morph into speech

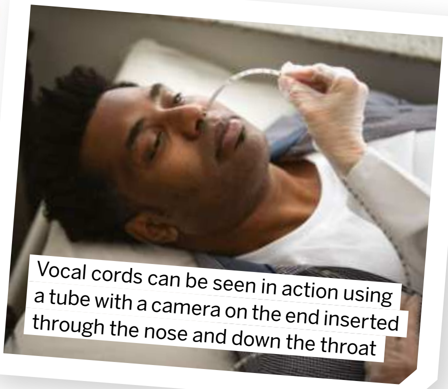


3 CONNECTIONS
Air flows through the trachea, into the larynx and up and outward into the throat and mouth.

4 TOP-DOWN VIEW
The vocal folds are found inside the middle of the larynx, either side of the air cavity known as the glottis.

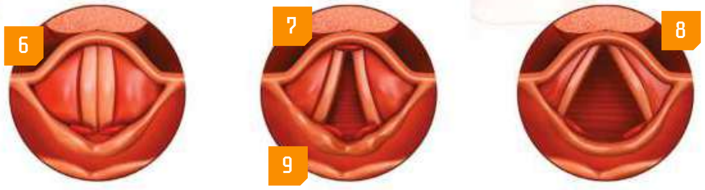
5 CONTROL
The intrinsic muscles of the larynx control the length, tension and opening and closing of the vocal folds inside.

Did you know?
A male's 'Adam's apple' is the front of the larynx



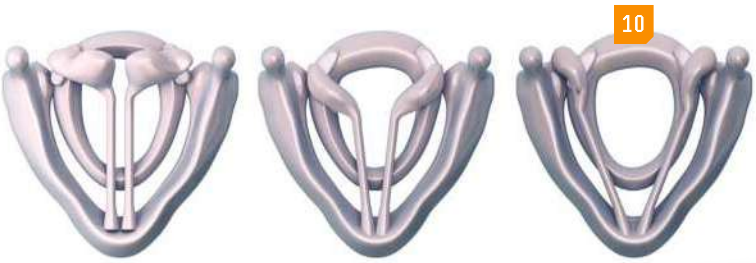
Vocal cords can be seen in action using a tube with a camera on the end inserted through the nose and down the throat

7 VIBRATIONS
Air forces the folds aside, and they rapidly come back together before parting again. This causes vibrations which are the source of the sounds we hear.



6 ADDUCTION
When making sounds the vocal folds are drawn together, meaning the air must push past them on its way out of the lungs.

8 ABDUCTION
When breathing the vocal folds are pulled apart, which allows air to pass through easily and soundlessly.

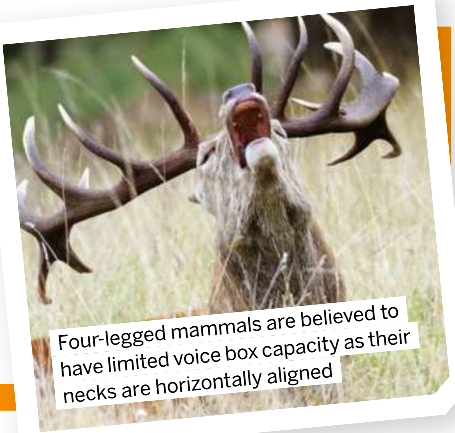


9 CONTROLLING PITCH
When the vocal folds relax, they shorten and create a lower pitch of vibrations. When they contract, they lengthen and generate a higher pitch.

10 LAYERS
The vocal cords are made up of an outer layer of mucus, flexible muscle and a structural layer of cartilage.

EVOLUTION OF OUR VOICES

Animals communicate through vocalising: birds sing, toads croak, whales call, lions roar. But as far as we know, no other animal has the depth and breadth of sound range to rival a human. A wide array of vertebrates including some fish, amphibians, reptiles, birds and mammals make sounds using the flow of air. These are often less complex than the sophisticated vocalisation systems in mammals, which include abdominal muscles and a diaphragm to regulate and control airflow and a network of muscles that support the voice box. Experts believe that humans have better vocal control than their four-legged mammal cousins as they are bipedal. Standing upright allowed for the larynx to move and for the throat cavity to expand.



Four-legged mammals are believed to have limited voice box capacity as their necks are horizontally aligned

© Getty

EXTREME STARS

From the biggest and brightest to the smallest and dimmest, we take a look at some stellar extremes

WORDS **ANDREW MAY**

DID YOU KNOW? If a red supergiant was placed at the centre of the Solar System, it would engulf the orbit of Jupiter

Two supergiants make up Orion: Betelgeuse at the top (red) and Rigel at the bottom (blue)

The Sun produces heat and light through nuclear fusion, converting hydrogen into helium. In this respect, it's a pretty typical star. Around 90 per cent of all stars are undergoing the same process, referred to as the main sequence of the stellar life cycle. Even so, there are some striking exceptions, such as stars of very low or very high mass or ones that have exhausted all their nuclear fuel. Here we take a look at some of these extreme stars – from brown dwarfs to supergiants and from neutron stars to weird hybrid stars. But first it's worth reviewing the basics of stellar evolution.

Although the stars in the night sky look similar to the naked eye, there's actually a wide variety of stellar types. This is partly because we see different stars at different points in their evolutionary cycle. This proceeds much too slowly for us to observe directly, so each star is like a single snapshot along the evolutionary path. It begins in a cloud of interstellar gas, where knots can form with sufficient mass that they start to collapse under their own gravity. As the collapse proceeds, the material gets hotter and denser, eventually forming protostars. Not all protostars are equal, even those formed in the same interstellar cloud at the same time. They come in a wide range of masses, from much smaller than our own Sun to many times larger. What happens next depends on the mass of the protostar. All but the very lowest mass stars soon become hot enough for nuclear fusion to take place, putting them on the main sequence. Somewhat paradoxically, however, it's the high-mass stars that burn through their nuclear fuel most rapidly before moving on to the later – and often much more dramatic – phases of stellar evolution.

© NASA / ESA / Getty

BROWN DWARFS

Shining only very dimly, these low-mass objects are sometimes classed as failed stars

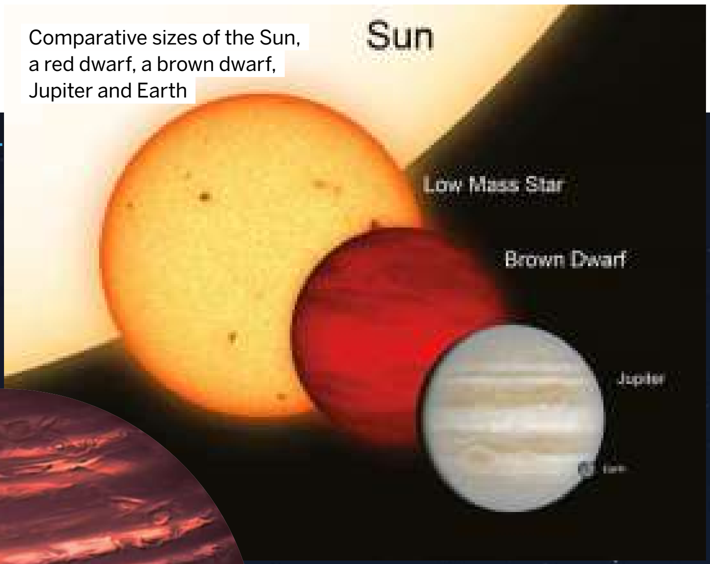
STATS

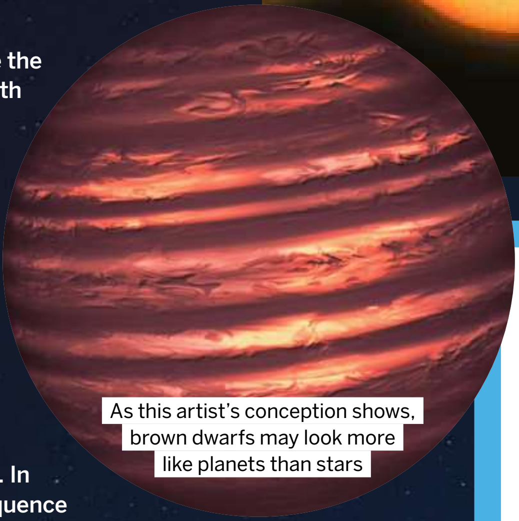
STAR MASS:
0.01 to 0.08 solar masses

STAR DIAMETER:
0.06 to 0.12 solar diameters

STAR LIFETIME:
Trillions of years

Brown dwarfs are the smallest stars, with masses in the range of 15 to 75 times the mass of the planet Jupiter. Like an ordinary star, a brown dwarf starts life by collapsing under its own gravity from a cloud of interstellar gas, but it doesn't have enough mass for the core temperature to rise to the point where hydrogen undergoes nuclear fusion. In other words, it never reaches the main sequence phase of stellar evolution. So why is a brown dwarf a star and not simply a very large planet? The reason is that while it's insufficient for ordinary hydrogen fusion, the core temperature is high enough for another kind of fusion involving a scarcer isotope called deuterium. This means the brown dwarf shines, albeit very dimly, with its own light – something a planet can't do. Even after all the deuterium is used up, the brown dwarf's retained heat means that it still radiates more energy than a planet. As it slowly cools down, this radiation declines from reddish light similar to a more conventional hydrogen-burning red dwarf star to very dim infrared light that is only barely perceptible, even with a powerful telescope.


Comparative sizes of the Sun, a red dwarf, a brown dwarf, Jupiter and Earth


As this artist's conception shows, brown dwarfs may look more like planets than stars

BLUE SUPERGIANTS

These are extremely massive young stars that have already used up most of their hydrogen fuel and are now fusing helium into heavier elements. Despite their size and luminosity, they're actually very rare, accounting for less than one in a thousand of the stars in the galaxy. There are two reasons for this. To start with, when clusters of stars form in interstellar gas clouds, the distribution of masses is strongly biased towards low-mass stars. Secondly, high-mass stars have very short life spans – only about 10 million years compared to 10 billion or more for our own Sun.

Blue supergiants are easiest to find in young star clusters like this one

SUPERGIANT STARS

The brightest stars in the galaxy live fast and die young

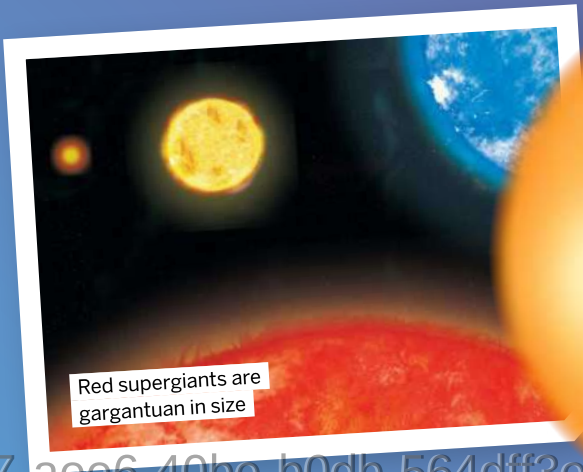
STATS

STAR MASS:
10+ solar masses

STAR DIAMETER:
30 to 500 solar diameters

STAR LIFETIME:
10 million years

Astronomers classify stars according to two main parameters: their intrinsic luminosity and their colour. In these terms, a supergiant is simply any star that lies at the upper end of the luminosity range. But there's actually quite a difference between blue and red supergiants. A blue supergiant is a comparatively young star that's so incredibly massive that it burns through all its hydrogen – and hence exits the main sequence – after just a few million years. On the other hand, a red supergiant is a star of somewhat lower mass, though still more than ten times that of our own Sun, that is nearing the end of its life. After passing through the red giant phase of its evolution, it begins a final phase of carbon-forming nuclear fusion, causing it to expand to truly enormous dimensions.


Red supergiants are gargantuan in size

The red supergiant Antares is so large that telescopes can resolve features on its surface

DID YOU KNOW? Although a brown dwarf has much more mass than Jupiter, it's similar in size because it's more compressed

NEUTRON STARS

The densest stars of all are more massive than the Sun but only ten miles across

STATS

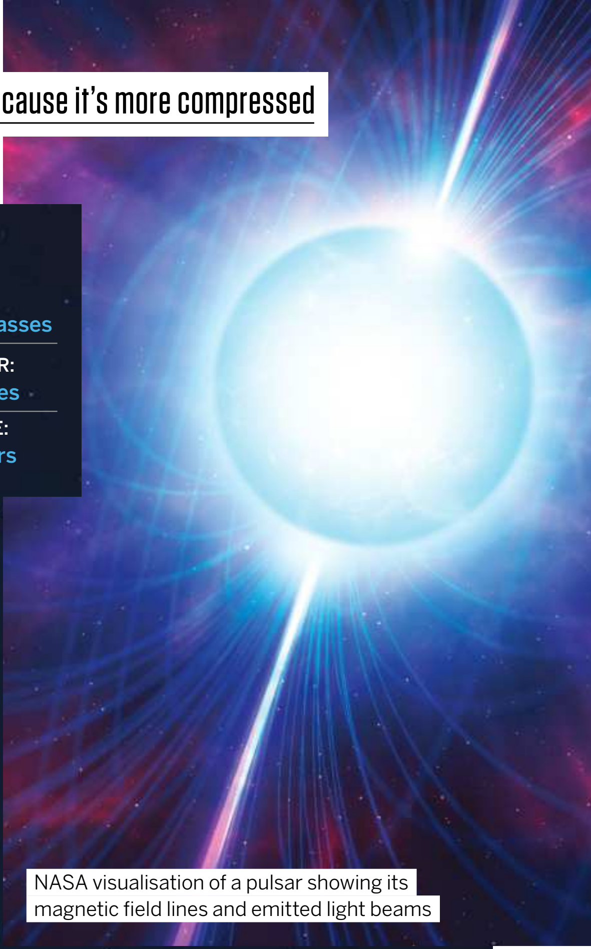
STAR MASS:
1.4 to 3.2 solar masses

STAR DIAMETER:
6.2 to 18.6 miles

STAR LIFETIME:
Billions of years

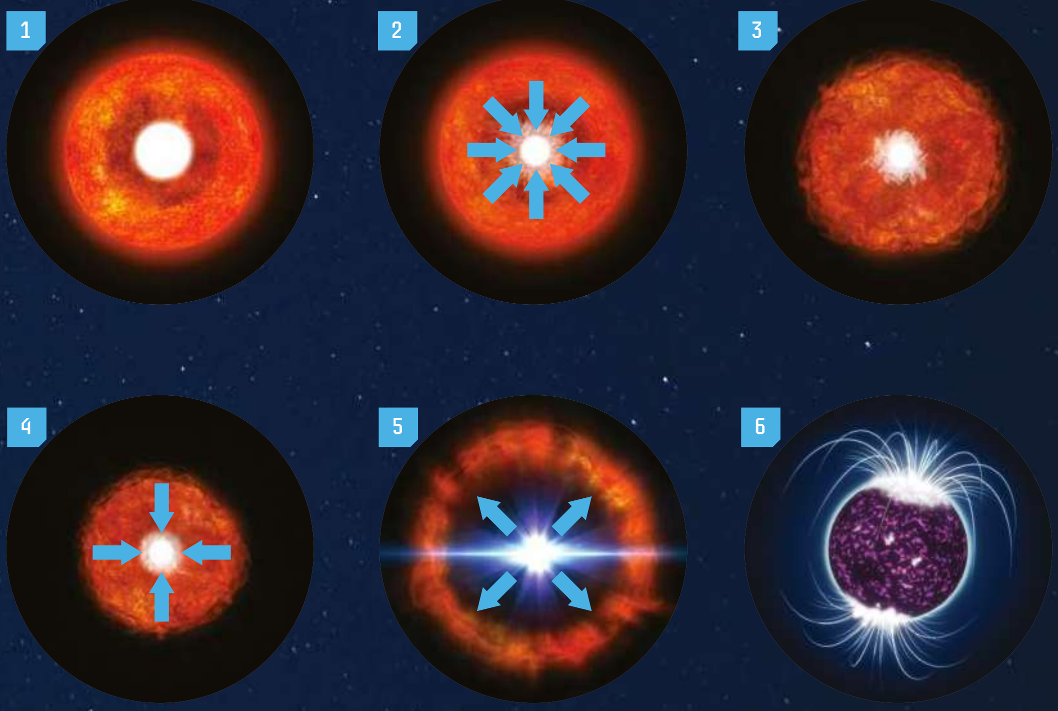
Normal atoms are composed of electrons, protons and neutrons, but if they're squashed together forcefully enough then the protons and electrons combine to form further neutrons, and eventually that's all that's left. The result is one of the most extreme forms of matter known to science, and it's what neutron stars are made of. A neutron star is one of the possible outcomes when a star finally runs out of nuclear fuel and collapses under its own gravity. Small and medium-sized stars like the Sun end up as white dwarfs, while the most massive stars become black holes. In between the two, the end result is a neutron star, an object more massive than the Sun but compressed down into a volume the size of a city. Under normal circumstances it would be virtually impossible to observe a neutron star. But fortunately for astronomers, some of them give their presence away in a highly dramatic form as a pulsar. These are rapidly spinning neutron stars with strong magnetic fields which emit high-energy beams that can be detected as regular flashes of radiation when they periodically point towards Earth.

Did you know?
A spoonful of neutron star is as heavy as Mount Everest


NASA visualisation of a pulsar showing its magnetic field lines and emitted light beams

MAKING OF A NEUTRON STAR

This is the ultimate fate of most stars between around 10 and 25 solar masses



1 MASSIVE STAR
For stars in this class, the final stages of main sequence evolution produce an iron-rich inner core.

2 CORE COLLAPSE
When all the nuclear fuel has been used up, the dense core collapses under its own gravity.

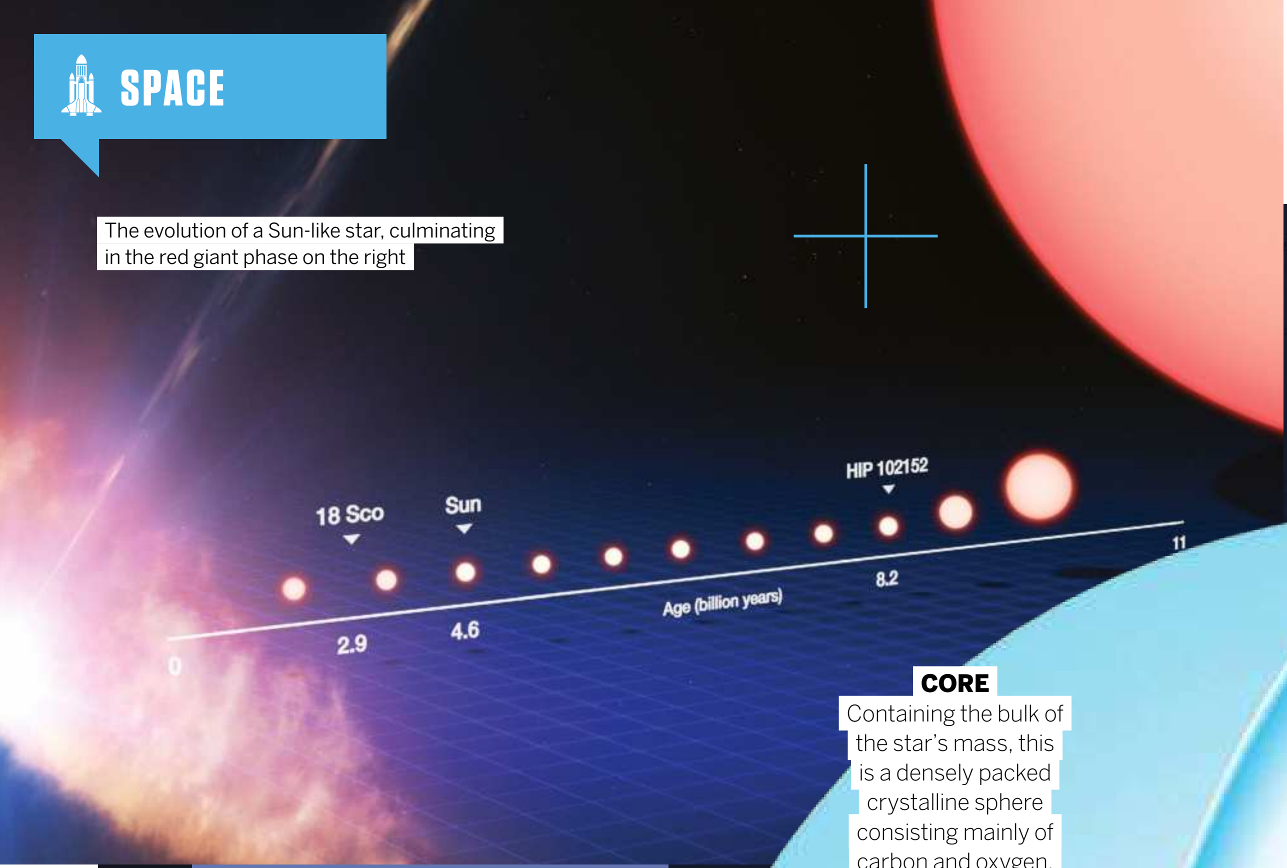
3 NEUTRON FORMATION
As gravity compresses the atoms in the core, electrons and protons are squashed together to form neutrons.

4 OUTER LAYER COLLAPSE
The star's outer layers also start to collapse, falling into the core at a quarter of the speed of light.

5 SUPERNOVA EXPLOSION
The energy generated by the collapsing core blows off the outer layers in a spectacular supernova explosion.

6 NEUTRON STAR
All that remains is the incredibly dense core, composed almost entirely of neutrons.

© Getty / European Southern Observatory / Wiki: Planetkid32 / NASA / Illustration by Adrian Mann



The evolution of a Sun-like star, culminating in the red giant phase on the right

RED GIANTS

A dramatic phase of stellar evolution that lies in the Sun's own future

STATS

STAR MASS:
0.3 to 10 solar masses

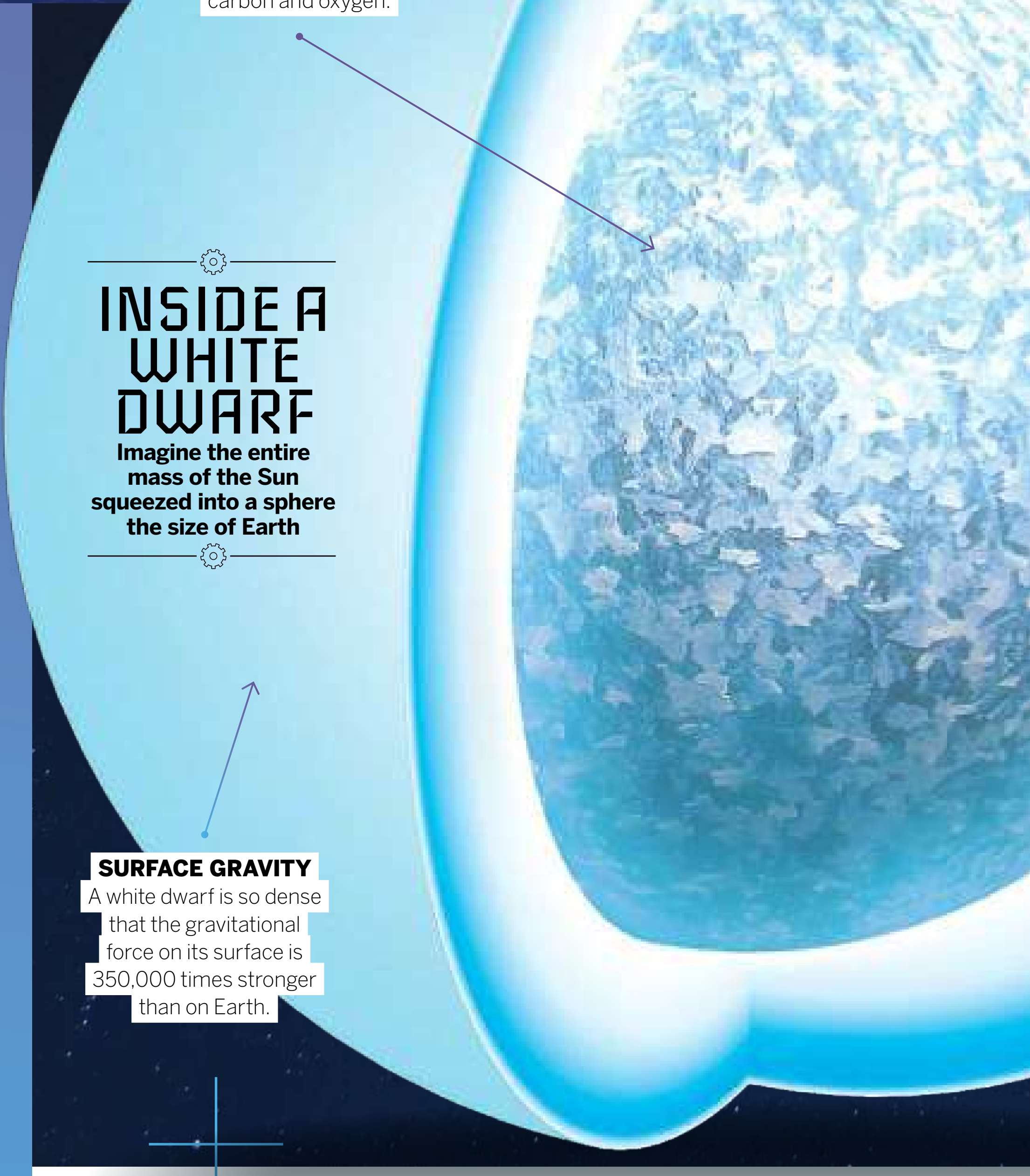
STAR DIAMETER:
20 to 100 solar diameters

STAR LIFETIME:
Over 100 million years

Most of the extreme stars we've listed here differ from our own Sun in that they started out with lower masses, like brown dwarfs, or higher masses, like supergiants and neutron stars. The Sun's evolution will never take it in any of those directions. On the other hand, there are two extreme phases of the stellar life cycle that do lie in the Sun's own future: the red giant phase and the white dwarf phase. Currently the Sun is on the main sequence, converting hydrogen into helium via nuclear fusion. This phase is expected to end in about 5 billion years, after which the Sun will expand into a red giant so huge that it engulfs the planets Mercury and Venus – and possibly even Earth. The energy for this expansion, which is of the star's outer layers only, actually comes from a contraction as the core shrinks down and heats up.

INSIDE A WHITE DWARF

Imagine the entire mass of the Sun squeezed into a sphere the size of Earth



HYDROGEN SHELL
A residual amount of hydrogen that hasn't been consumed by nuclear fusion makes up the outermost layer.

CORE
Containing the bulk of the star's mass, this is a densely packed crystalline sphere consisting mainly of carbon and oxygen.

SURFACE GRAVITY
A white dwarf is so dense that the gravitational force on its surface is 350,000 times stronger than on Earth.

DID YOU KNOW? Around a third of the 6,000 or so stars that can be seen at night with the unaided eye are red giants

WHITE DWARFS

The surprisingly extreme fate of an ordinary star like the Sun

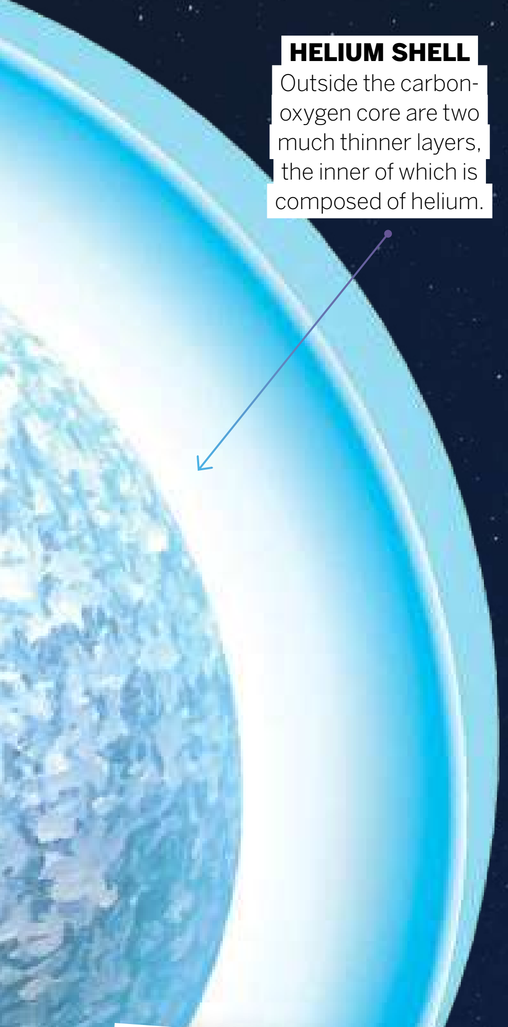
A white dwarf represents the final stage in the evolution of a star like the Sun, following on from the comparatively brief red giant phase. During the previous phase, the core of the star was gradually shrinking and getting hotter while the outer layers expanded to enormous proportions. Eventually the core generates so much energy that it blows the outer layers off completely, leaving just the dense hot core behind. This core is the white dwarf, which will continue to exist, gradually losing its accumulated heat, for many billions of years. Although a white dwarf is extremely dense by ordinary standards, it's not as dense as a neutron star, where all the matter has been compressed down to neutrons. While a neutron star packs all of a star's mass into a volume just a few miles across, a white dwarf is around the same size as Earth. It's still composed of atomic nuclei and electrons like ordinary matter, but squashed down to the point where the separation between electrons is comparable to their wavelength. This produces a phenomenon called degeneracy pressure which supports the white dwarf against any further collapse.

STATS

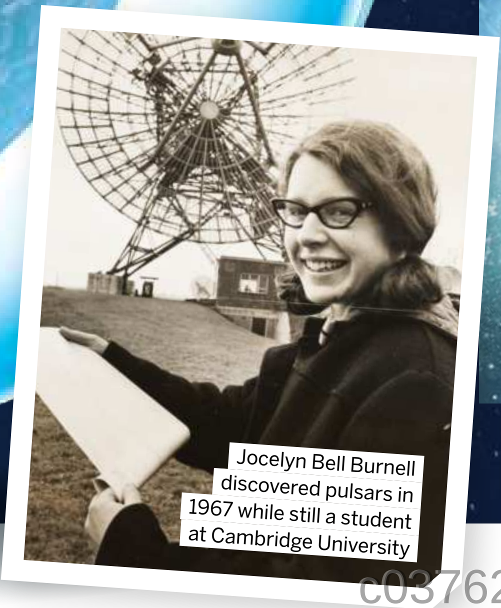
STAR MASS:
0.1 to 1.4 solar masses

STAR DIAMETER:
Around one Earth diameter

STAR LIFETIME:
Billions of years


HELIUM SHELL
Outside the carbon-oxygen core are two much thinner layers, the inner of which is composed of helium.

Artist's impression of a newly collapsed, superdense and very hot white dwarf star


Jocelyn Bell Burnell discovered pulsars in 1967 while still a student at Cambridge University

A STAR WITHIN A STAR?

We speak to astrophysicist Cole Miller about hypothetical hybrid stars known as Thorne–Żytkow objects

Miller is a professor of astronomy at the University of Maryland

What is a Thorne-Żytkow object?

A hypothetical object in which a red giant or supergiant – with a radius on the order of the Earth-Sun distance – contains a neutron star in its core. Neutron stars and regular stars can orbit each other, and the suggestion is that when the regular star evolves into the red giant phase it might sometimes swallow the neutron star.

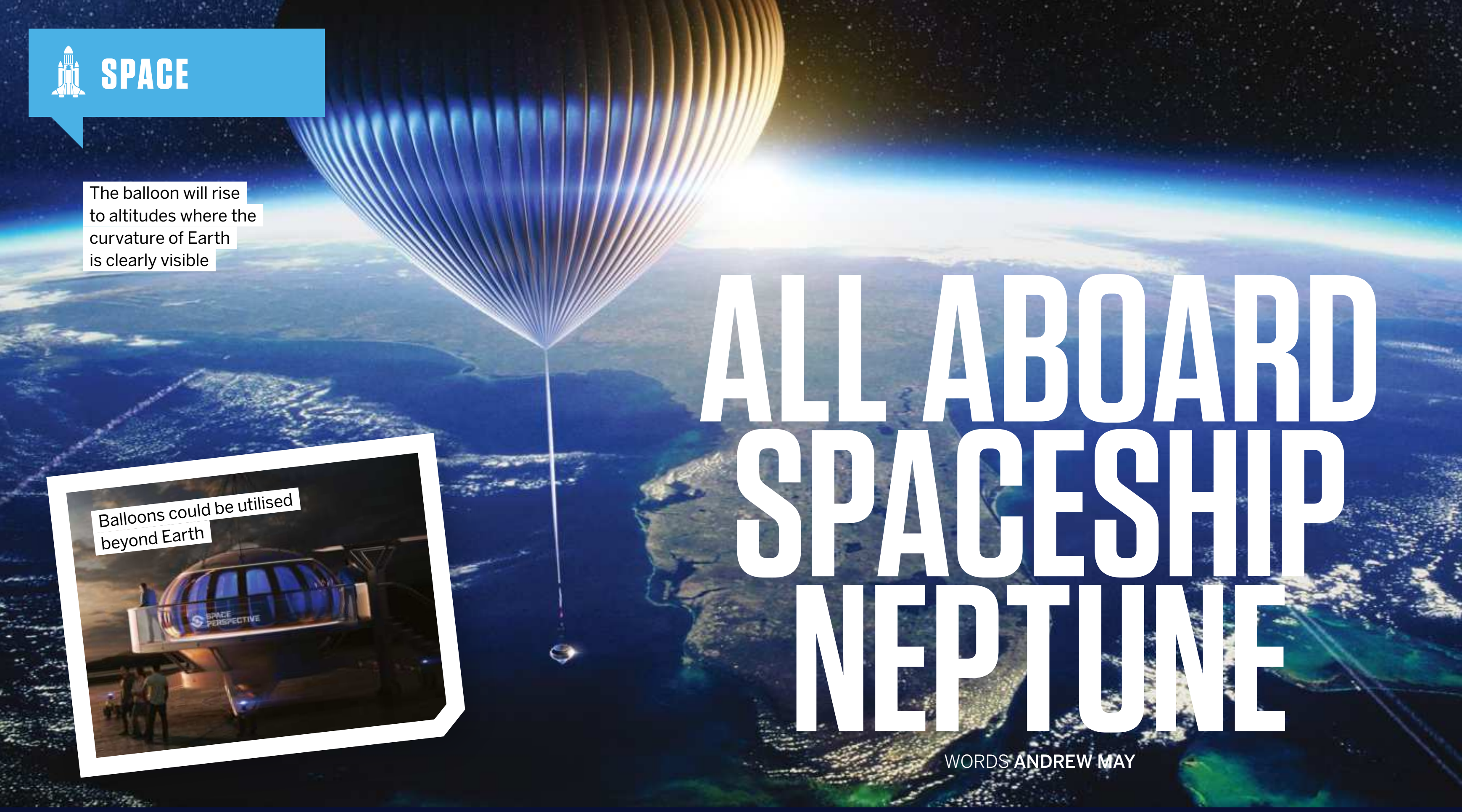
What's the history behind this weird-sounding idea?

An early suggestion was by the great Soviet physicist Lev Landau, who proposed in 1938 that a small neutron star core at the centre of normal stars could provide their power sources. That turns out not to work, but in 1977 Kip Thorne and Anna Żytkow of the California Institute of Technology made the suggestion that bears their names. Landau hoped that the idea would be amazing enough to save him from arrest as a dissident in Stalinist Russia, but it didn't work and he spent a year in prison.

Are these objects purely theoretical, or have they actually been observed?

The evidence isn't clear because differences from standard red giant stars are subtle. As Thorne and Żytkow noted, such stars "are thoroughly hidden from the prying eyes of the astronomer by the huge, tenuous red-giant envelope". It could be that the abundances of certain isotopes would be different than normal in such stars. There was a report in 2014 that a star named HV 2112 has anomalous abundances of the element rubidium and the expected very high luminosity – about 100,000 times that of the Sun. However, in 2018 a reanalysis by another group found a lower luminosity and no excess of rubidium. At the same time, the 2018 paper proposed its own stellar candidate, HV 11417, so there is still hope.

© Getty / European Southern Observatory / Cole Miller



The balloon will rise to altitudes where the curvature of Earth is clearly visible

Balloons could be utilised beyond Earth

ALL ABOARD SPACESHIP NEPTUNE

WORDS **ANDREW MAY**

In this latest space tourism venture, a company is planning balloon flights to the edge of space

Imagine travelling high enough to see the curvature of Earth against the blackness of space, not in a brief, high-adrenaline rocket ride but a luxurious and leisurely balloon flight up into the stratosphere. That's the experience a company called Space Perspective is hoping to offer aspiring space tourists with its Spaceship Neptune balloon, currently under development. Despite its name, Spaceship Neptune won't actually reach space, which officially starts at the Kármán line 62 miles above Earth's surface.

When a balloon is filled with a low-density gas such as hydrogen or helium, its resulting buoyancy causes it to rise up through the atmosphere because the balloon is lighter than the volume of air it displaces. As it rises higher and higher, the surrounding air gets thinner and thinner, and eventually the balloon is confronted by Archimedes' principle, which halts the ascent when the ambient density is the same as its own. For a balloon like Spaceship Neptune, this will happen at an altitude of around 20 miles.

Fortunately, from the point of view of the passengers carried by the balloon, this is just a technicality. Even from an altitude of 20 miles they will be able to see the blackness of space above them and the spherical Earth below in a view not too different from that at the Kármán line. And thanks to Archimedes' principle, once they reach their peak altitude they will just float there, rather than falling back to Earth like a suborbital rocket. This permits a much longer experience, with Space Perspective proposing six-hour missions: two hours ascending through the stratosphere, two hours floating at maximum altitude and two hours descending to a gentle splashdown in the ocean.

Did you know?

The balloon's passenger capsule is five metres across

A LUXURY SPACESHIP

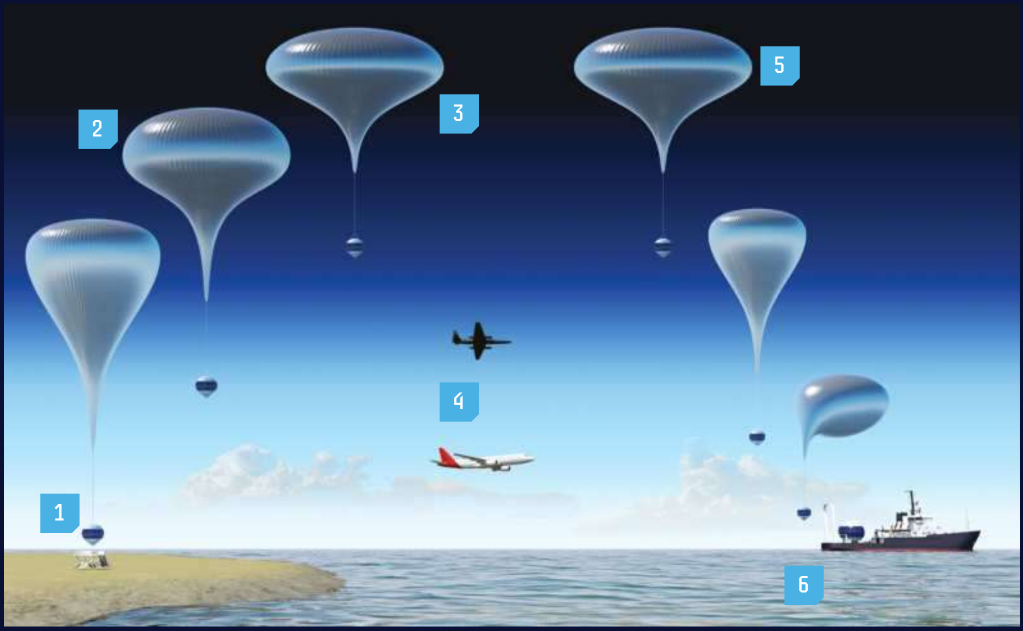
Although Spaceship Neptune won't reach the Kármán line, it will go above another key boundary called the Armstrong line. Located around 12 miles altitude, the air pressure here is so low that water boils at normal body temperature. In order to survive, this means humans need either a spacesuit or a pressurised cabin. Fortunately for Space Perspective's customers, Spaceship Neptune will be equipped with the latter in the form of a state-of-the-art capsule suspended beneath the balloon. But it isn't the kind of cramped, utilitarian capsule normally associated with space travel. It's both spacious and luxurious, giving the occupants 360-degree panoramic views. The interior will be maintained at a comfortable temperature using a thermal control system and reflective coatings on the outside surfaces to minimise solar heating. For even greater passenger comfort, the cabin includes reclining seats and couches, mood lighting and even food and beverage services.

Spaceship Neptune will launch from NASA's iconic Kennedy Space Center in Florida

DID YOU KNOW? The Armstrong line is named after US Air Force General Harry Armstrong, not astronaut Neil Armstrong

FLIGHT TO THE EDGE OF SPACE

Spaceship Neptune will take passengers on a relaxing six-hour flight with spectacular views



1
LIFTOFF

The balloon departs from a specially designed launchpad on the Florida coast.

2
ASCENT

Spaceship Neptune rises through the atmosphere at a steady 12 miles per hour, giving passengers a comfortable ride.

3
FLOAT ALTITUDE

The balloon reaches its point of neutral buoyancy at a height of almost 20 miles, above 99 per cent of the atmosphere.

4
CONVENTIONAL AIRCRAFT

In comparison, commercial jets fly at around 8.5 miles altitude and the Lockheed U-2 spy plane at 14 miles.

5
DESCENT

After spending two hours at its peak altitude, the balloon gently descends to a splashdown in the sea.

6
DISEMBARKATION

The balloon capsule is recovered onto a ship, where the passengers disembark.

NASA routinely uses large high-altitude balloons like this one for scientific research

Travellers on Spaceship Neptune will experience stunning views of Earth and space

A SPACE TOURIST'S OPTIONS

SPACE PERSPECTIVE SPACESHIP NEPTUNE	VIRGIN GALACTIC SPACESHIPTWO	BLUE ORIGIN NEW SHEPARD	SPACEX CREW DRAGON
COST PER TICKET: $125,000	COST PER TICKET: $450,000	COST PER TICKET: Undisclosed	COST PER TICKET: Undisclosed
FLIGHT METHOD: Balloon	FLIGHT METHOD: Spaceplane	FLIGHT METHOD: Suborbital rocket	FLIGHT METHOD: Orbital spacecraft
MAX ALTITUDE: 20 miles	MAX ALTITUDE: 55 miles	MAX ALTITUDE: 65 miles	MAX ALTITUDE: 360 miles
FIRST TEST FLIGHT DATE: June 2021	FIRST TEST FLIGHT DATE: December 2018	FIRST TEST FLIGHT DATE: November 2015	FIRST TEST FLIGHT DATE: March 2019

THE SPACE BALLOON

As high-tech as Spaceship Neptune's passenger capsule is, it's lifted into the stratosphere by one of the oldest aeronautical technologies: a balloon. This doesn't require any engines, but simply ascends spontaneously because it's lighter than air – in other words, when filled with gas at ground level it weighs less than the air it's displaced. This is the easiest way to reach high altitudes, and NASA frequently uses helium-filled balloons, made from thin polyethylene film, for upper-atmosphere research. Spaceship Neptune will use the same kind of balloon as NASA, but filled with hydrogen gas instead of helium because the latter is in short supply.

The first test flight of the Spaceship Neptune balloon took place in June 2021

© Space Perspective / Getty / NASA / illustration by Adrian Mann

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DID YOU KNOW? The average milk yield in the UK is 8,214 litres per cow per year

Animal

How humans created modern-day farm animals

DOMESTICATION

WORDS **SCOTT DUTFIELD**

It's fair to say that the domestication of animals is one of the most important advancements in human history. Known as the Neolithic Revolution, around 12,000 years ago humans began cultivating the land and breeding animals for livestock. The principle of livestock domestication centres around selectively breeding wild animals with traits beneficial for humans – for meat, milk or materials. Over millennia, humans have bred generations of animals like cows, sheep, pigs and chickens to enhance qualities such as their muscle mass for meat and wool production for fabrics.

The first wild animal to be taken by humans from its natural environment was the predecessor of the modern-day sheep, the Asiatic mouflon (*Ovis orientalis*), around 11,000 years ago. Since then, humans have captured and domesticated 38 different species, including 8,800 different breeds, from around the world.

The specific techniques that primitive farmers used to tame and domesticate livestock throughout history are largely unknown to archaeologists. However, in 2014 researchers uncovered some clues in an ancient settlement in Turkey. Around 11,000 years ago, a small village on the banks of the Melendiz River in Turkey was home to some of the earliest domesticated animals. By studying the changes in bones at the site, known as Aşıklı Höyük, archaeologists noticed a shift in the remains of wild animals such as hares, deer and goats, to predominantly sheep remains. By around 9,500 years ago almost 90 per cent of the bones being left at the site were from sheep, 58 per cent of which were from females, typical among flocks for breeding

Did you know?

There are more than 1.7 billion sheep across the world

Chickens descended from red junglefowl (*Gallus gallus*)

HUMAN-MADE ANIMALS

Cats, dogs and cattle aren't the only animals that humans have altered through domestication. Without human intervention, animals such as pigeons and goldfish wouldn't exist. More than 400 million pigeons live around the world, and they all descend from a domestic species called the rock dove (*Columba livia*). These birds originated in ancient Mesopotamia and Egypt and were enticed into the city as a source of food around 10,000 years ago. Throughout history, rock doves – and subsequently pigeons – have proven to be more beneficial than a quick meal thanks to their navigational skills as messenger pigeons. Naturally, captive pigeons found their way out of breeding centres and into cities, benefiting from the cliff-like buildings for their nests and bountiful sources of food. Now, in an age where pigeon pilots are no longer needed for sending messages, the world is left with a species of bird that wouldn't have existed without humans.

Modern-day pigeons are the result of escaped worker pigeons

© Getty

Alpacas were first domesticated in the Puna region of Peru

purposes. The remains were found in areas researchers believed to be pens in the middle of the village, used to acclimatise the sheep to humans. Villagers likely introduced young sheep as pets to their villages, too.

The theory as to why wild sheep were originally stabled is related to other agricultural processes, such as crop growing. As prolific hunters, early farmers may have had to weigh up spending time further afield hunting compared to time spent on crop farming. To optimise their time, hunters brought their prey to the farm to breed and produce a sustainable supply of food to the village while still tending their crops.

Animal domestication and human evolution are intertwined. Not only have humans bred livestock and changed the biology of domestic animals, but domestic animals have also affected how humans have evolved. One of the most apparent examples lies in our ability to digest a sugar called lactose. As infants, many mammal species begin their lives suckling milk from their mothers. However, at varying points in time infants are weaned off their milk supply, losing their ability to process lactose and either becoming plant-munching herbivores or flesh-eating predators. Humans, on the other hand, developed a tolerance for the milk sugar, known as lactase persistence. A genetic mutation, lactase persistence enables the continued production of an enzyme that can break down lactose and metabolise it.

Although the ancient ancestors of modern cows, called aurochs, were originally domesticated solely for their meat around 10,000 years ago, around 6,000 years ago dairy farming began among European farmers, roughly around the same time humans developed a tolerance for lactose past infancy. Now lactose persistence is found in around 35 per cent of adults globally.

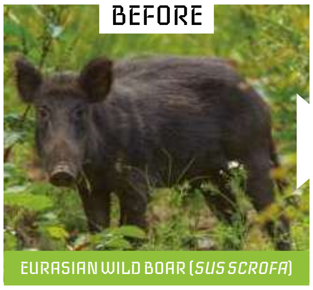
But domestication isn't all it's cracked up to be. Although raising livestock has facilitated the advancement of human civilisation, it's also brought with it disease. During the evolution of animal domestication, confining animals has facilitated the transmission of pathogens and parasites to humans – for example tuberculosis among cows and influenza from pigs.

Did you know?

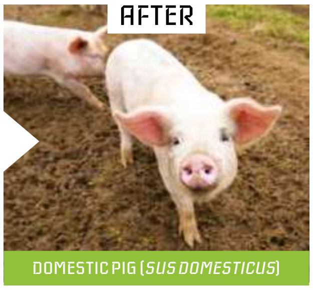
Pigs don't have sweat glands

THEN AND NOW

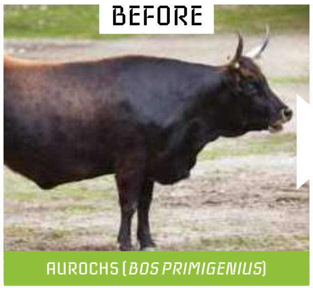
What livestock looked like before humans domesticated them



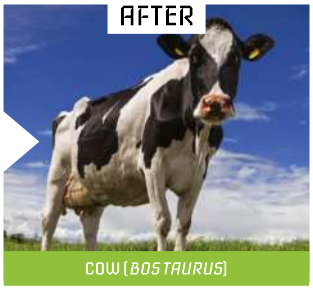
EURASIAN WILD BOAR (*SUS SCROFA*)



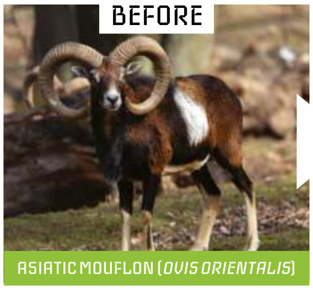
DOMESTIC PIG (*SUS DOMESTICUS*)



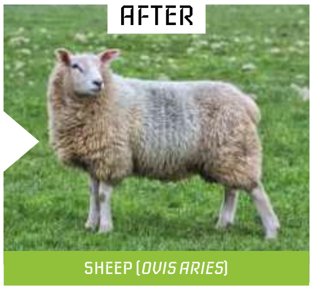
AUROCHS (*BOS PRIMIGENIUS*)



COW (*BOS TAURUS*)



ASIATIC MOUFLON (*OVIS ORIENTALIS*)



SHEEP (*OVIS ARIES*)

DOMESTICATION SYNDROME

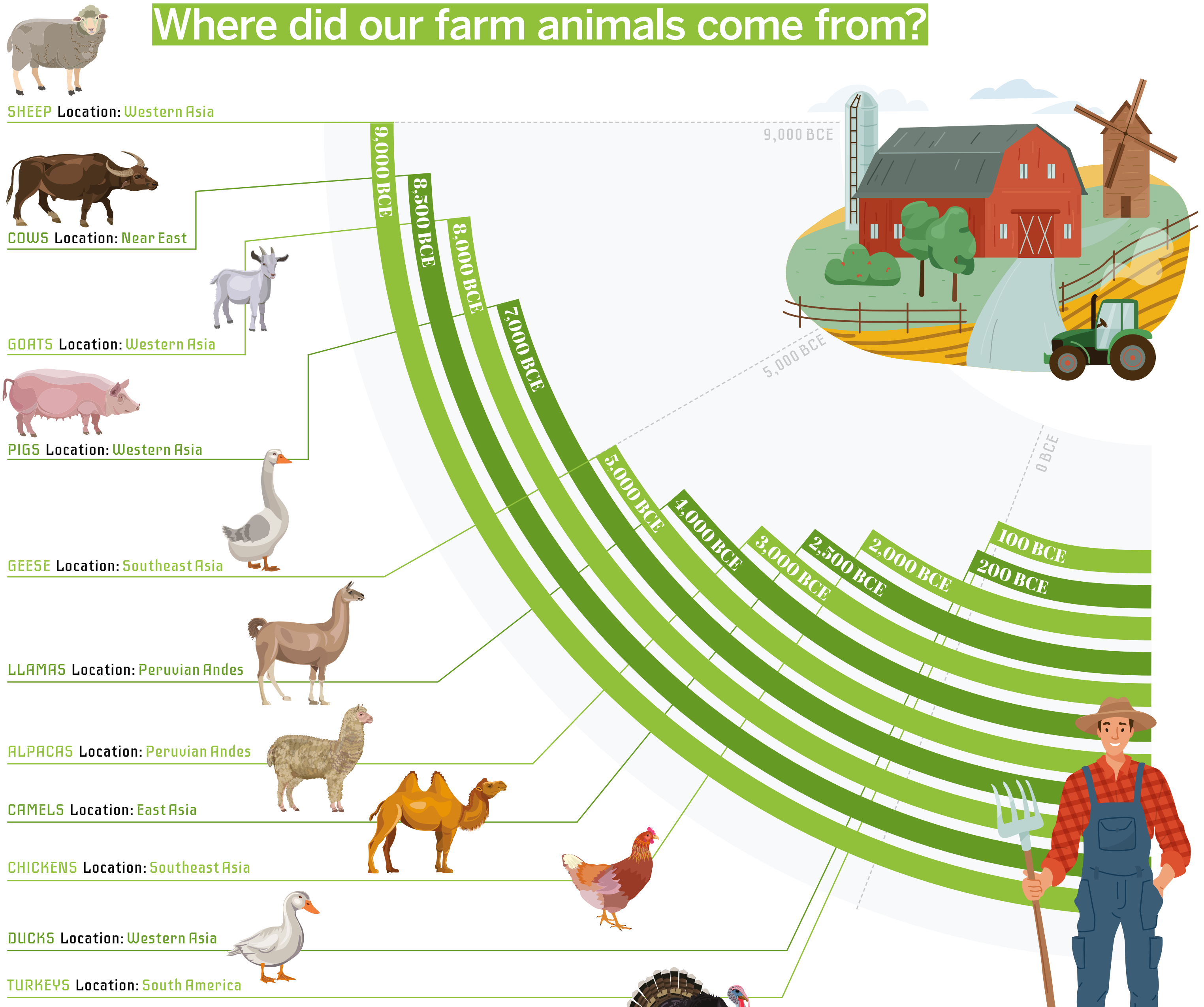
Why is it that so many domesticated animals look so far removed from their wild ancestors? The answer lies in a phenomenon called domestication syndrome. When you look at any domesticated animal, you'll notice a lot of them share common physical and behavioural traits, including floppy ears, tameness and changes in their tails. Scientists have been studying this since Charles Darwin proposed it in 1868. Russian scientist Dmitry Belyaev conducted an experiment where silver foxes were selectively bred for tameness. After 45 generations of selecting for this behaviour, the foxes had become more like dogs, with wagging tails and floppy ears. The syndrome remains largely a mystery, but some scientists have suggested that selecting for tameness affects cell development during an animal's embryonic stage.

One of the silver foxes from the Russian domestication experiment

DID YOU KNOW? A single sheep can produce 4.5 kilograms of wool per year

Domestication AROUND THE WORLD

Where did our farm animals come from?



SHEEP Location: Western Asia

COWS Location: Near East

GOATS Location: Western Asia

PIGS Location: Western Asia

GEESE Location: Southeast Asia

LLAMAS Location: Peruvian Andes

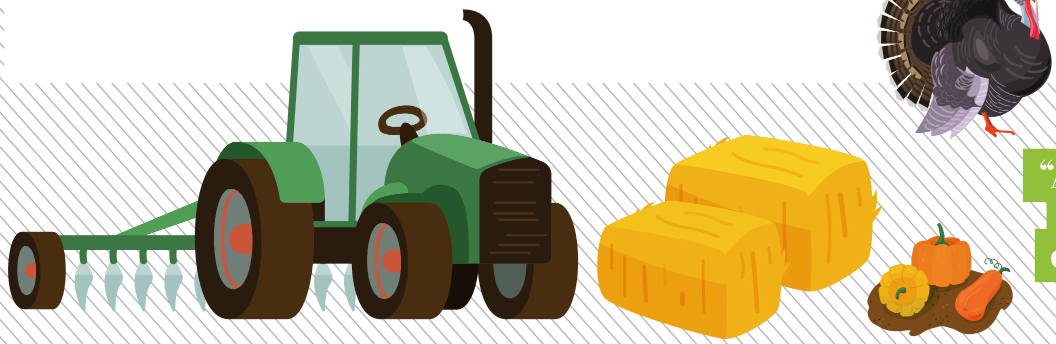
ALPACAS Location: Peruvian Andes

CAMELS Location: East Asia

CHICKENS Location: Southeast Asia

DUCKS Location: Western Asia

TURKEYS Location: South America



> "Although raising livestock has facilitated the advancement of human civilisation, it's also brought with it disease"

© Alamy / Getty

EMPEROR PENGUINS: SURVIVAL SPECIALISTS

How the world's largest penguins live in the harshest continent on the planet

WORDS **SCOTT DUTFIELD**

Meet Antarctica's giant, the emperor penguin (*Aptenodytes forsteri*). Of the 18 species of penguins on Earth, emperor penguins are the largest, standing over a metre tall. Along with being the biggest, they're also the southernmost bird species in the world, enduring the harsh weather conditions of the Antarctic continent where they exclusively live. Currently, there's a population of about 595,000 penguins that make up around 54 different colonies in Antarctica.

During their breeding season between March and April, emperor penguins experience Antarctic temperatures that plunge as low as -50 degrees Celsius. Unlike a lot of bird species, male emperor penguins spend the majority of their time incubating their offspring. After a female lays a single egg in May, she will venture out into the ocean to feed for around nine weeks. During this time the male will balance the new egg on his feet and swaddle it with his body. While incubating, a male penguin can lose around 45 per cent of his body weight, as they are unable to feed during this time.

As a colony, emperor penguins band together in their thousands to form one enormous huddle to battle against the chilling 93-mile-per-hour winds of the Antarctic. Nestled within the huddle, the temperature can reach almost 37 degrees Celsius. In August, the females return from their food tour of the Southern Ocean to feed their newly hatched chicks. Having now handed over their parental responsibility, male penguins journey out to hunt and replenish their lost body weight. After a few weeks the males return, and both penguin parents protect and feed their young into adulthood.

© Getty

Emperor penguins have been recorded spending as much as 28 minutes underwater

PENGUIN PETROL

Emperor penguins face an uncertain future. Along with large predators such as leopard seals chasing their tails, the climate crisis is hot on the heels of these big birds. Research has shown that under current global emissions and the rate of melting of sea ice, emperor penguins could become extinct by the end of the century. To monitor the effects of climate change on emperor penguins, researchers at Woods Hole Oceanographic Institution (WHOI) have deployed a robot called ECHO onto the ice. As part of a 30-year program, ECHO autonomously travels and tracks radio frequency identification tags that have been implanted into penguin chicks. The data ECHO collects includes population numbers, geographical movements and hunting behaviours.

ADAPTED FOR ANTARCTICA

These giant penguins have an arsenal of highly specialised adaptations to combat the extreme cold and scarcity of food

1 BIG BIRDS
Emperor penguins can weigh up to 40 kilograms and stand up to 1.3 metres tall.

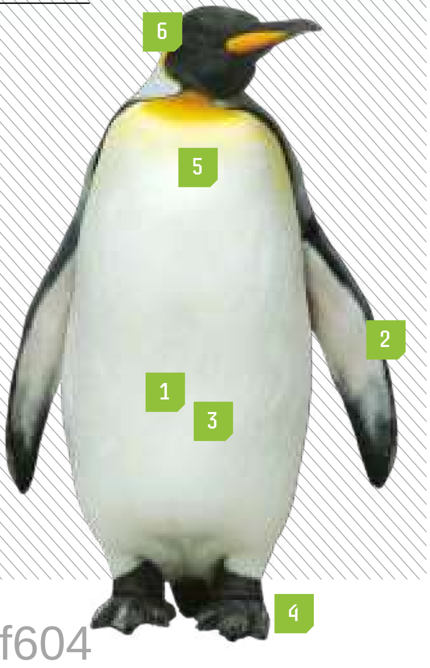
2 EXPERT SWIMMERS
With a hydrodynamic body and powerful wings, they commonly dive up to 40 metres at around 6.7 miles per hour.

3 FULL STOMACHS
Penguins feed on mostly fish and krill. An adult can eat up to three kilograms of food per day.

4 STRONG GRIP
Short legs and strong claws allow penguins to grip onto rocks and ice.

5 INSULATION
By preening their feathers, emperor penguins trap air between their densely packed feathers for insulation.

6 SALTY TEARS
Penguins have glands under their eyes that secret excess salt, allowing them to drink salt water safely.



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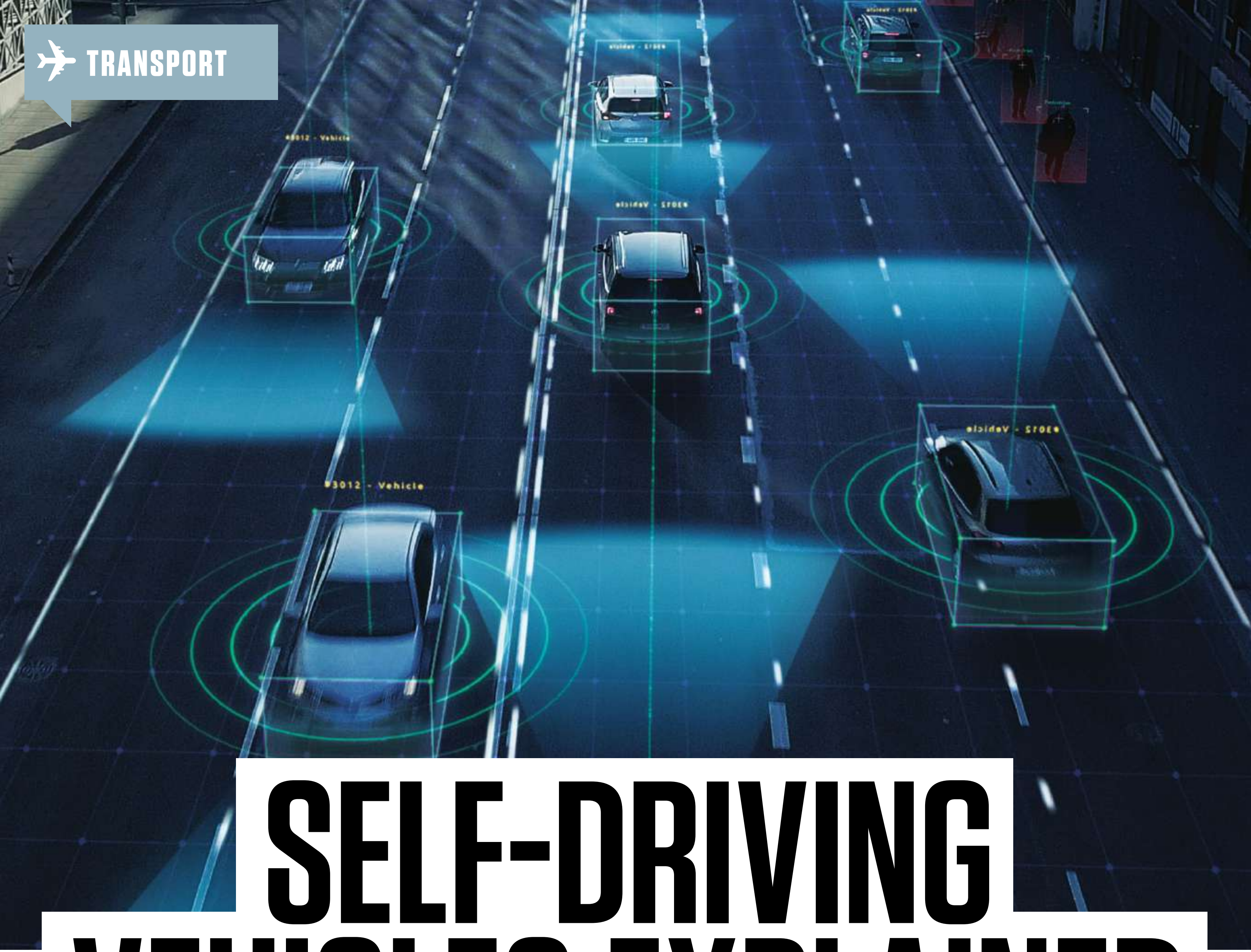


SELF-DRIVING VEHICLES EXPLAINED

How this evolving technology is changing the dynamics of traffic and the way we drive

WORDS **AILSA HARVEY**

Have you ever taken a driving lesson, failed a driving test or just experienced the sheer concentration required by a driver along a busy street? The age restrictions and examinations in place before being able to take control of a vehicle on the road all centre around safety. This is because driving a car isn't an instinctive act, even for an experienced driver. The rules of the road and situational attentiveness have to be learned through guided lessons. And just as traditional cars need drivers deemed fit for the road, autonomous vehicles need to possess intelligent technology.

Before autonomous vehicles can take over our roads, one of the biggest issues to address is the ethics of the car software. If a person behind the wheel unexpectedly finds themselves close to hitting a pedestrian, their split-second decision of whether to swerve, and in which direction, lies with them. But software developers have to preprogram self-driving cars, and without being able to preempt each individual accident scenario, decide in advance whether the car should save the driver and passengers at the expense of pedestrians, or vice versa?

Without the added unpredictability of roads, autonomous software is believed to provide faster response times than humans. Self-driving cars also reduce cases of drunk driving. While autonomous driving already exists on our roads today, manufacturers of self-driving cars request that their drivers pay attention at all times in order to intervene in an emergency situation while these ethical questions are investigated further.

DID YOU KNOW? Autonomous vehicles could reduce fatalities by more than 90 per cent

HOW DOES AUTOPILOT WORK?

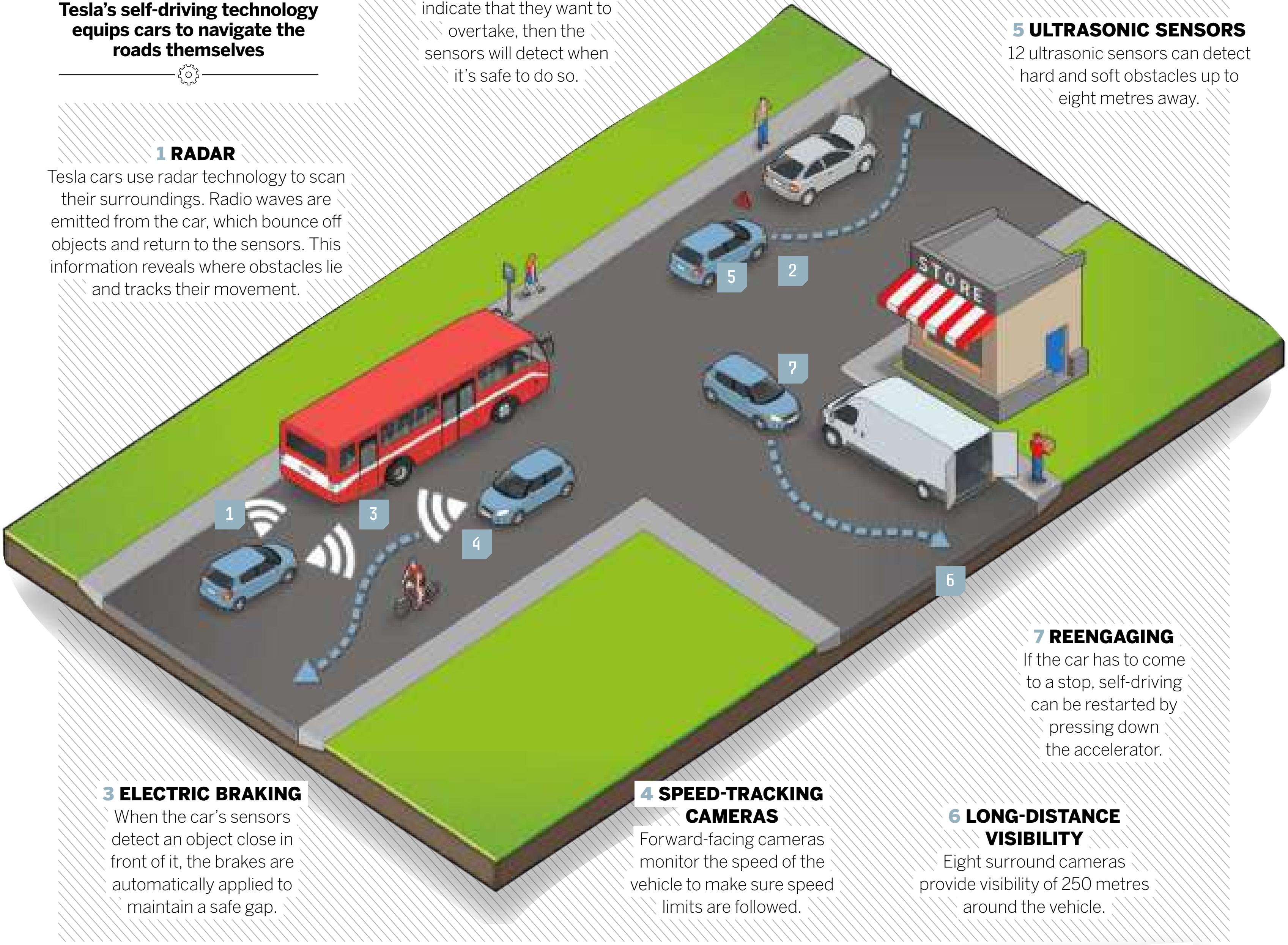
Tesla's self-driving technology equips cars to navigate the roads themselves

1 RADAR
Tesla cars use radar technology to scan their surroundings. Radio waves are emitted from the car, which bounce off objects and return to the sensors. This information reveals where obstacles lie and tracks their movement.

2 OVERTAKING
To change lanes and overtake, Tesla's Autopilot requires the driver to indicate that they want to overtake, then the sensors will detect when it's safe to do so.

Did you know?
There are over 1,400 self-driving cars in the US

5 ULTRASONIC SENSORS
12 ultrasonic sensors can detect hard and soft obstacles up to eight metres away.



7 REENGAGING
If the car has to come to a stop, self-driving can be restarted by pressing down the accelerator.

3 ELECTRIC BRAKING
When the car's sensors detect an object close in front of it, the brakes are automatically applied to maintain a safe gap.

4 SPEED-TRACKING CAMERAS
Forward-facing cameras monitor the speed of the vehicle to make sure speed limits are followed.

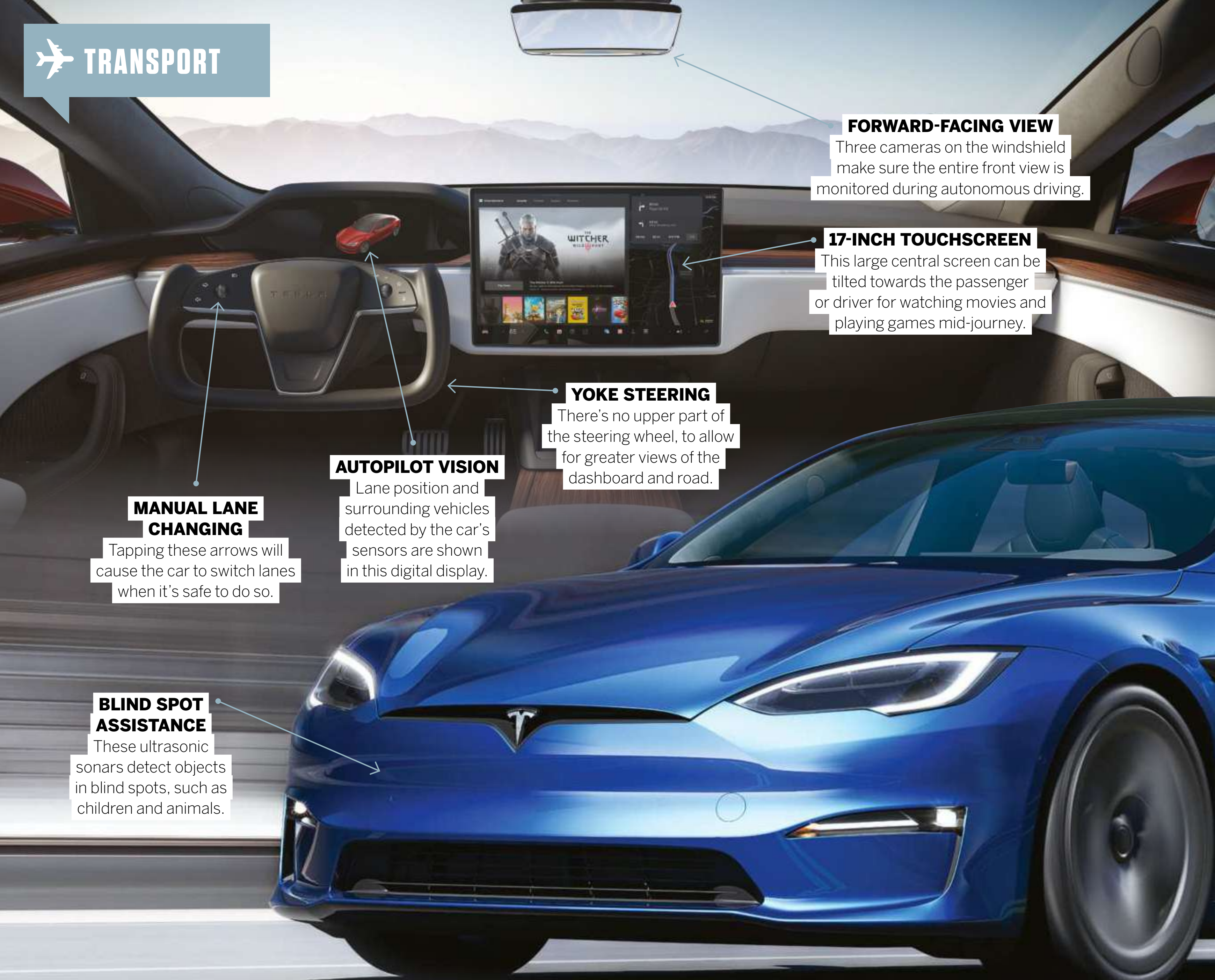
6 LONG-DISTANCE VISIBILITY
Eight surround cameras provide visibility of 250 metres around the vehicle.

AUTONOMOUS AIRPORTS

Driverless vehicles aren't restricted to busy roads; they can also help increase the efficiency of crowded areas like airports. Airports can cover huge areas of land, so travelling between terminals is a common necessity for passengers who arrive at them. Fully electric autonomous vehicles can reduce emissions and maximise the flow of airports. This includes transferring passengers, who select the terminal or other destination on an airport shuttle pod's touchscreen display, and transporting bags from planes to luggage carousels. These pods can be equipped with cameras, radar and lidar sensors both on the sides of the vehicle and along the pathways that guide them.

Autonomous pods are being used in airports such as London Heathrow

© Getty



FORWARD-FACING VIEW
Three cameras on the windshield make sure the entire front view is monitored during autonomous driving.

17-INCH TOUCHSCREEN
This large central screen can be tilted towards the passenger or driver for watching movies and playing games mid-journey.

YOKE STEERING
There's no upper part of the steering wheel, to allow for greater views of the dashboard and road.

AUTOPILOT VISION
Lane position and surrounding vehicles detected by the car's sensors are shown in this digital display.

MANUAL LANE CHANGING
Tapping these arrows will cause the car to switch lanes when it's safe to do so.

BLIND SPOT ASSISTANCE
These ultrasonic sonars detect objects in blind spots, such as children and animals.

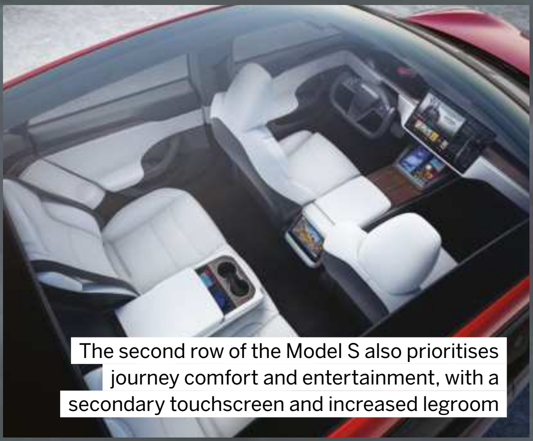
INSIDE TESLA'S MODEL S

The sleek 2022 Model S has improved vision for self-driving

REAR CAMERA
Above the licence plate is a camera that monitors activity behind the vehicle. When in reverse, the dashboard displays these images.

MOUNTED CAMERAS
Both front fenders feature side-view cameras.

DID YOU KNOW? Since Waymo vehicles were introduced to roads in 2009, they have covered over 20 million miles



The second row of the Model S also prioritises journey comfort and entertainment, with a secondary touchscreen and increased legroom

SIDE VIEW
Cameras located on the door pillars monitor surrounding obstacles and cars in adjacent lanes.

BLIND SPOT ASSISTANCE

5 CHALLENGES FOR AUTONOMOUS CARS

1 ACCIDENT LIABILITY
With nobody in control of self-driving cars, if an accident takes place it's less clear who is at fault.

2 RADAR INTERFERENCE
If self-driving cars become the norm on roads, busy conditions could result in radio waves emitted by other vehicles being picked up by nearby cars.

3 WEATHER CONDITIONS
Extreme fog or rainfall can reduce the functionality of autonomous sensors. Vehicles need to be better adapted for all weather conditions.

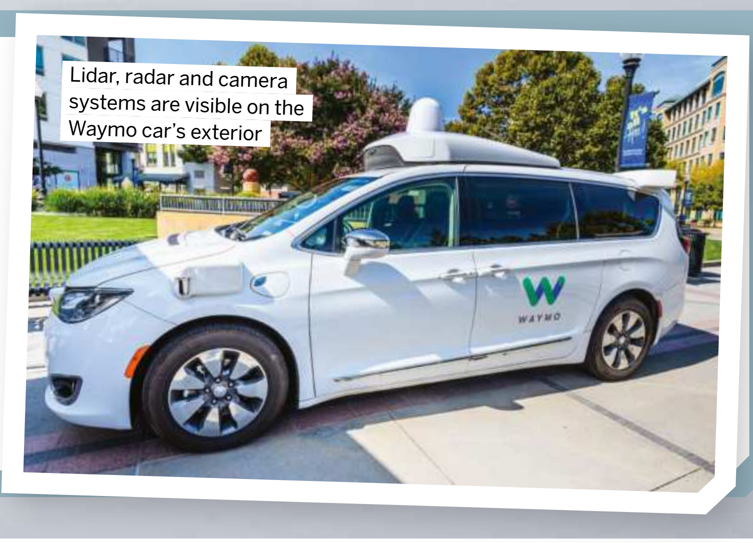
4 UNPREDICTABLE ROADS
Roads can be diverse. Those that don't have clear lane markings or involve long tunnels with reduced visibility for sensors could impact safety.

5 TRAFFIC CONDITIONS
Human behaviour is difficult to predict. Surprising movements or unexpected obstacles are more difficult to navigate and preplan for an autonomous vehicle's software.

Did you know?
The first driverless car was demonstrated in 1939

WAYMO TAXI SERVICE

American self-driving car company Waymo was previously known as the Google self-driving car project. However, with the car's new look comes a new vision. Currently operating in Phoenix, Arizona, Waymo is providing a driver-free taxi service. Using the Waymo app, users can view the availability of these vehicles and direct any free Waymo taxis to their precise location. Once inside, passengers use the touchscreen system to choose their destination. This can include up to five places on the way to the final destination, allowing riders to stop at a shop or run another errand. Although no human interaction is needed for the service, a button can be pressed in the case of an incident or query to speak to a support agent.



Lidar, radar and camera systems are visible on the Waymo car's exterior

© Alamy / Getty / Tesla

MAGLEV TRAINS: BENEATH THE RAILS

Did you know?

EDS systems use wheels until they reach a high enough speed

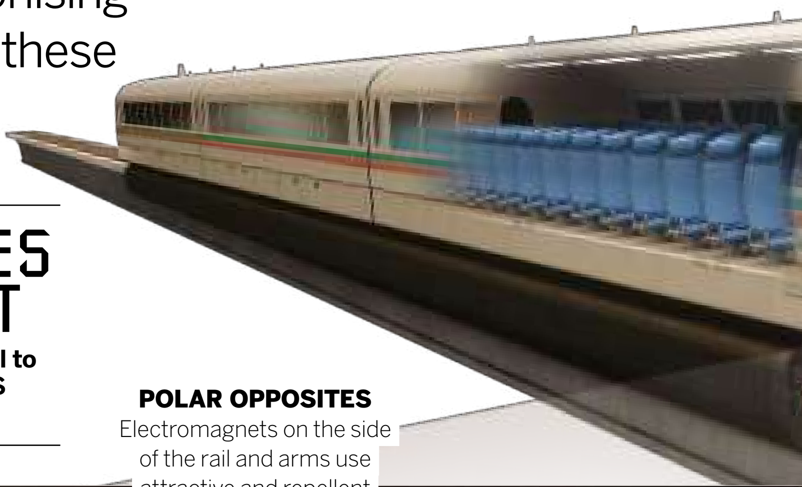
Superfast maglev technology is revolutionising train travel across the world. Here's how these mysterious magnetic marvels work

WORDS **MIKE JENNINGS**

If you've been on a train in the past few years then there's a good chance it was cramped, slow and old, but that won't be the case if maglev technology takes off. The word 'maglev' stands for magnetic levitation, and that name gives a clue about how these futuristic trains function.

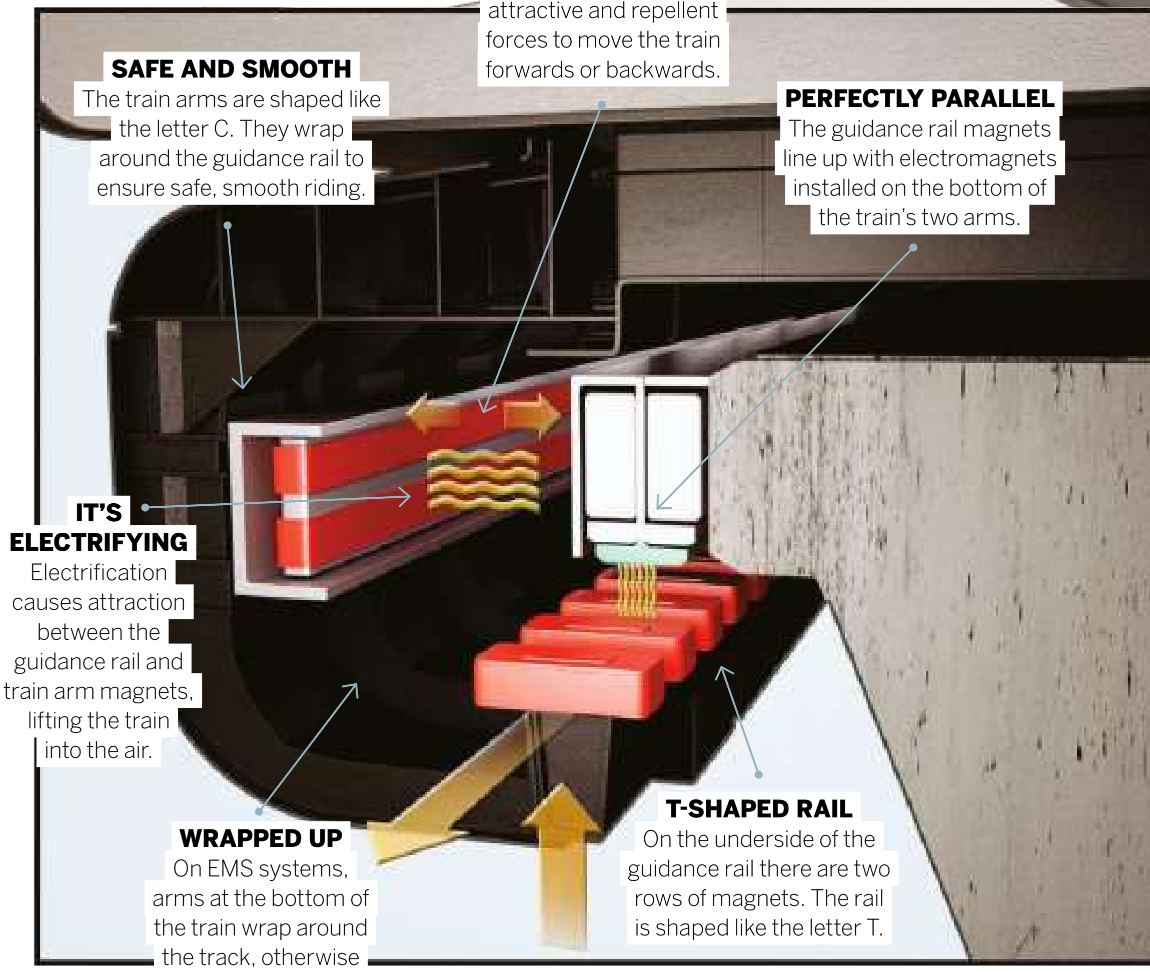
Two popular systems are in use today. The first deploys electromagnetic suspension, or EMS. In this structure, the bottom of the train wraps around a guidance rail. Magnets in the train and rail are attracted to each other, which lifts the train above the track. The second most common system is electrodynamic suspension, or EDS, which makes trains levitate with repellent magnets and superconductors instead. In both methods, horizontal rows of electrified magnets propel the train forwards and bring it to a stop.

Maglev sounds like something from the future, but there are plenty of reasons to rely on this technology today. Maglev trains are far faster than normal trains – commercial lines in Shanghai hit 270 miles per hour and prototype models are even quicker – so maglev transports can deliver shorter journeys and cover longer distances. Beyond that, their relative lack of moving parts means they don't need repairs so often, and they're not affected as badly by poor weather. They don't use engines that churn through fossil fuels, so they don't produce harmful emissions. The lack of an engine means they're quieter than conventional trains. They're safer, too, and less likely to derail. There are downsides, though. They're hugely expensive because they're built using new technology and can't integrate with existing rail infrastructure. EMS systems can vibrate too much because their levitation technology requires frequent small adjustments, while EDS networks can be unsafe for people with pacemakers, and even for some types of computer storage.



OPPOSITES ATTRACT

We peel back the metal to find out how an EMS system operates



POLAR OPPOSITES
Electromagnets on the side of the rail and arms use attractive and repellent forces to move the train forwards or backwards.

SAFE AND SMOOTH
The train arms are shaped like the letter C. They wrap around the guidance rail to ensure safe, smooth riding.

PERFECTLY PARALLEL
The guidance rail magnets line up with electromagnets installed on the bottom of the train's two arms.

IT'S ELECTRIFYING
Electrification causes attraction between the guidance rail and train arm magnets, lifting the train into the air.

WRAPPED UP
On EMS systems, arms at the bottom of the train wrap around the track, otherwise known as a guide rail.

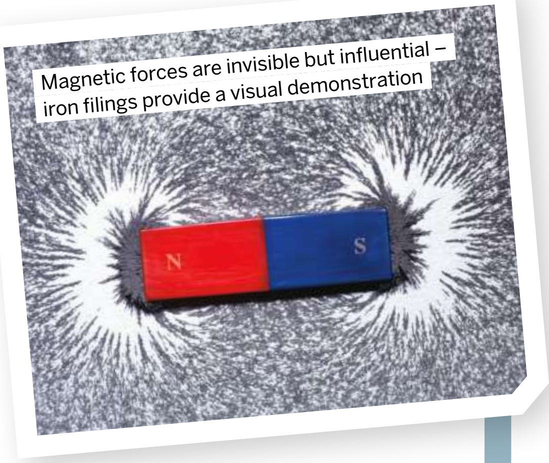
T-SHAPED RAIL
On the underside of the guidance rail there are two rows of magnets. The rail is shaped like the letter T.

DID YOU KNOW? Maglev trains use a cushion of air that's between one and ten centimetres tall

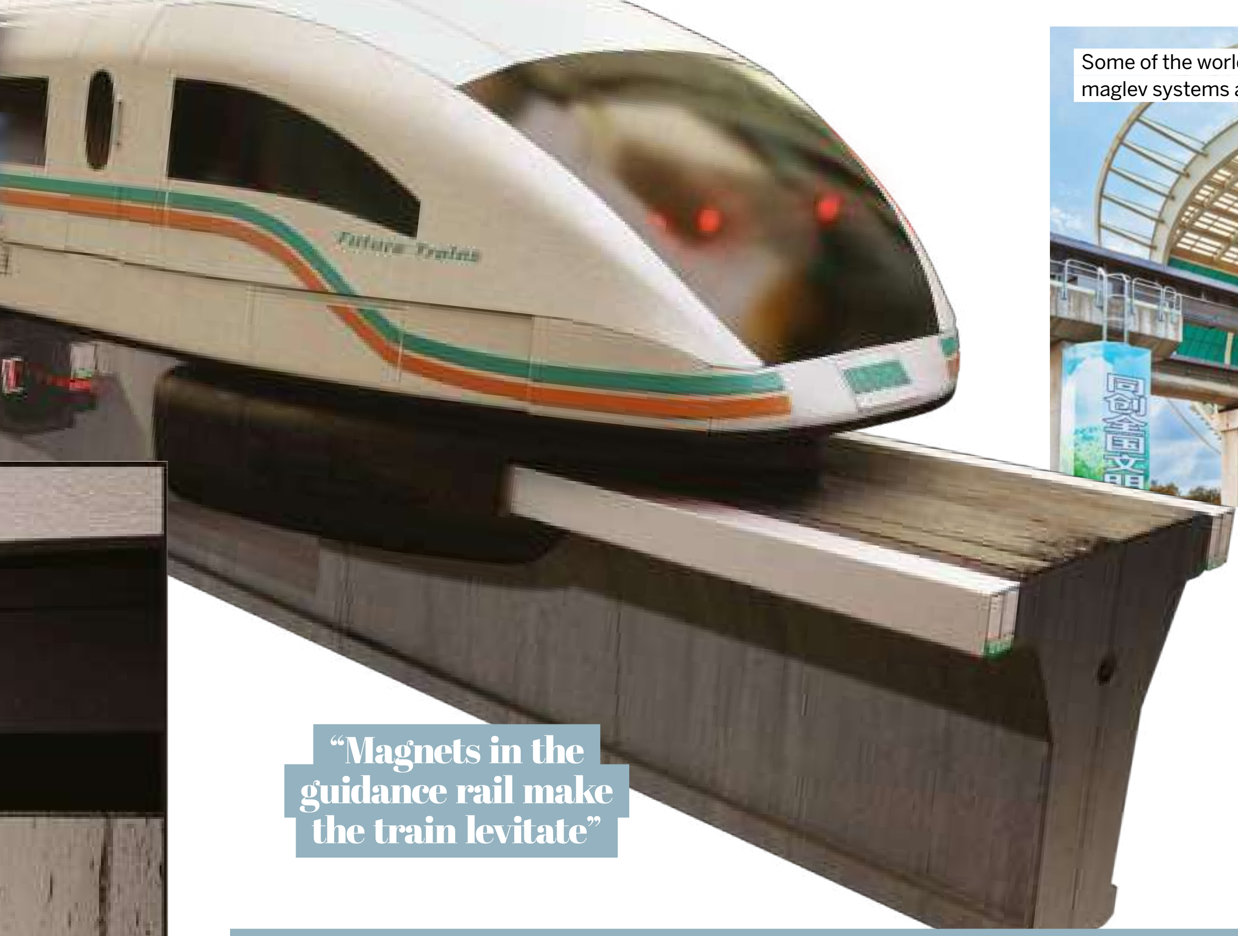
UNSEEN FORCES

Magnetism is the force that allows magnetic objects to bring others closer, or repel them. Each magnetic object has a north and south pole, and magnetic forces flow between those two points. Place an object's north or south pole near the same pole on another object and they'll be repelled. If you place opposite poles alongside each other, they'll be attracted instead. Indeed, Earth itself is a huge magnet, hence the north and south poles. Electric charges moving within particles create magnetic forces. And while magnetism is a natural force, humans build most magnets with electric currents. This is crucial, because you'll find magnets in almost every electronic or mechanical device you can think of, and manufacturers need to ensure their strength and stability.

Sometimes magnets are permanent, but on other occasions they're only magnetic when filled with an electric current, like in maglev propulsion systems.



Magnetic forces are invisible but influential – iron filings provide a visual demonstration



> "Magnets in the guidance rail make the train levitate"

Some of the world's most advanced maglev systems are found in China

MAGNETIC MOMENTUM

Maglev might sound futuristic, but the first patents for magnetic levitation transport systems were filed in the early 1900s, so it's hard to tell who invented the maglev train. Those patents became more sophisticated after the World War II, and in 1979 the first maglev train opened for passengers at a transport exhibition in Hamburg. It was called Transrapid 05 and was so popular that its opening times were extended. The world's first commercial maglev train was a low-speed airport shuttle that ferried passengers between Birmingham's airport and train stations, but it only operated for 11 years and used a 600-metre track.

Inventors have been experimenting with magnetic transport for more than 100 years

EXPRESS SERVICE

L0 SERIES

COUNTRY OF ORIGIN:
Japan
SPEED:
374 miles per hour

CRRC 600

COUNTRY OF ORIGIN:
China
SPEED:
372 miles per hour

MLX01

COUNTRY OF ORIGIN:
Japan
SPEED:
361 miles per hour

TR-09

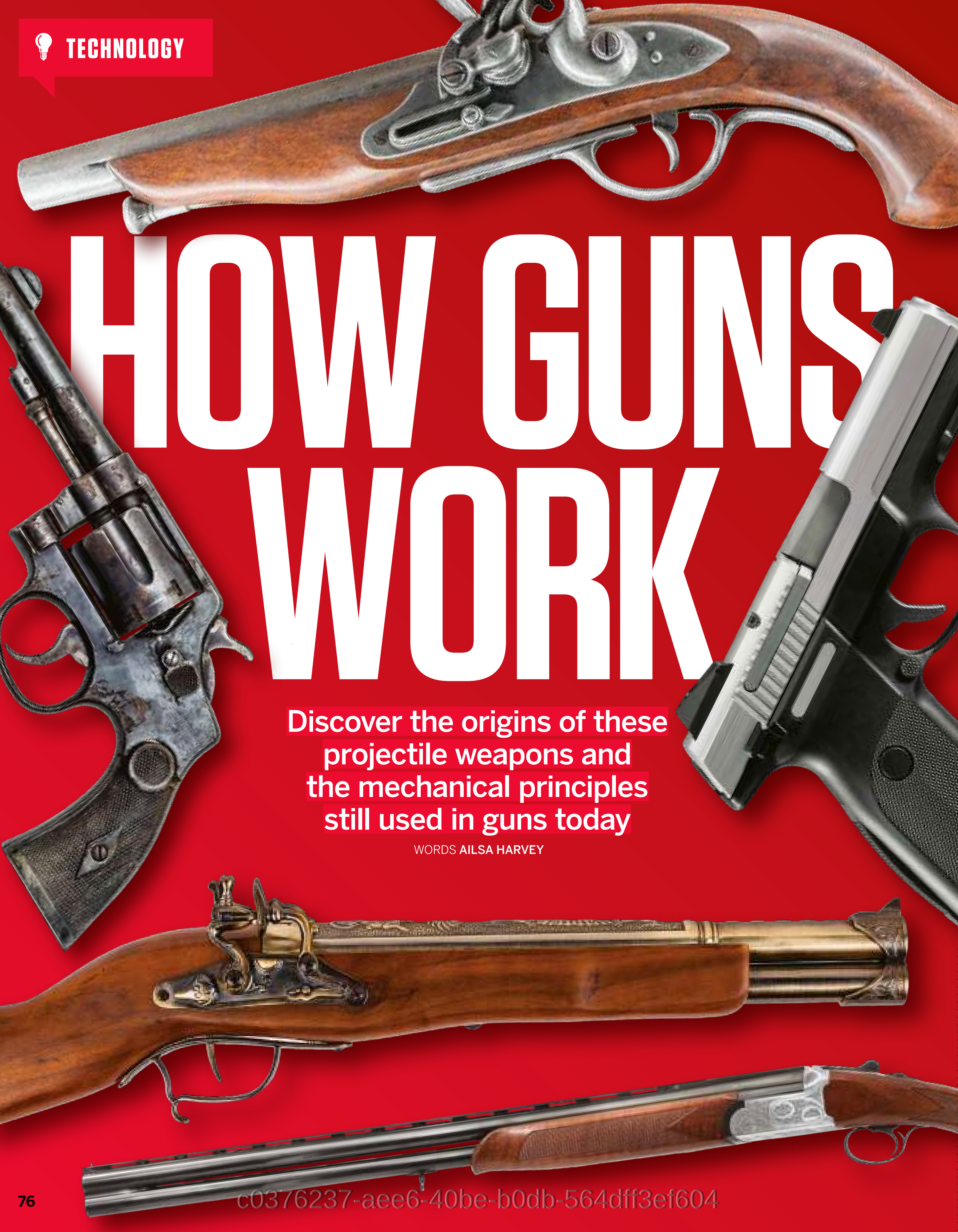
COUNTRY OF ORIGIN:
Germany
SPEED:
310 miles per hour

© Alamy / Getty / Illustration by Nicholas Forder

HOW GUNS WORK

Discover the origins of these projectile weapons and the mechanical principles still used in guns today

WORDS **AILSA HARVEY**



DID YOU KNOW? A bamboo tube was used to make the first gun

Early versions of guns are estimated to have been invented over 1,000 years ago, but the first record of their use in battle was during the Battle of Auray in 1364. This devastating technology was only made possible after the accidental discovery of gunpowder. In 850 BCE, Chinese experimenters were trying to create a powder that could be used to achieve eternal youth. Instead they discovered the explosive properties that resulted from combining charcoal, saltpetre and sulphur. The powder could be ignited and used to launch projectiles from cannons. Over time these cannons were improved, and smaller portable versions were developed – this was the birth of the modern gun.

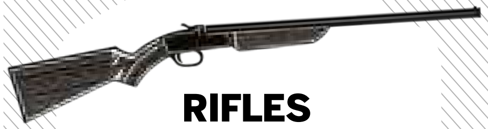
Today, semi-automatic and automatic guns are the most common types produced. Both are self-loading, but the difference between the two is what happens when the trigger is squeezed. Semi-automatic guns release one bullet every time the trigger is squeezed while automatically reloading the next one. Automatic guns will continuously reload and fire projectiles for as long as the trigger is held down, either until the gun's magazine is emptied of bullets or the user releases the trigger.

Did you know?

The rotation of revolvers is based on the design of a ship's wheel

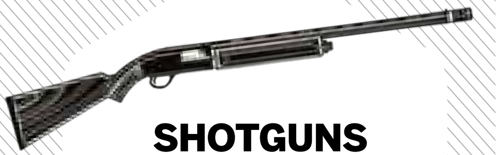
Shooting is a popular pastime and sport

TYPES OF GUNS



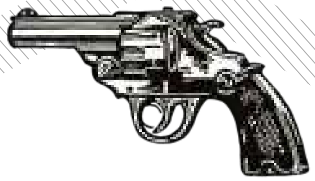
RIFLES

These are fired from shoulder level and contain grooves inside the barrel that cause the fired bullets to spin. This gives them a high level of accuracy for long-range shooting.



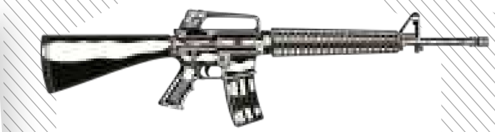
SHOTGUNS

These long-barrelled guns are mostly used for shooting small and moving targets such as birds. The cartridges contain hundreds of tiny pellets.



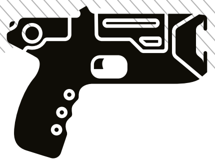
REVOLVERS

A small handgun. As bullets are fired, the cylinder holding them rotates to place a new bullet in line for firing, so several bullets can be shot before the gun needs to be reloaded.



MACHINE GUNS

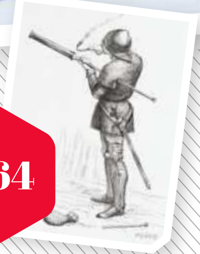
A machine gun is an automatic weapon that will fire bullets for as long as the trigger is pressed. Machine guns were invented for military use.



STUN GUNS

These non-lethal guns deliver an electric shock of around 1,200 volts via electrodes fired on conductive wires. These are used by both the armed forces and law-enforcement agencies.

Biathlons combine skiing and shooting



1364

This is the earliest record of humans using guns. They were called 'hand cannons'.

1380

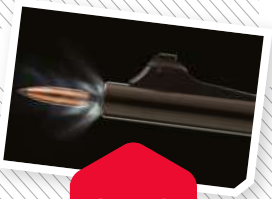
The use of handguns was widespread in Europe. These early guns involved lighting gunpowder to shoot projectiles through tubes.

1400s

The first guns that were mechanically fired, called matchlocks, were produced.

1509

The wheel lock was invented to make the first self-igniting guns. As the wheel rotates in a wheel lock, friction creates a spark.



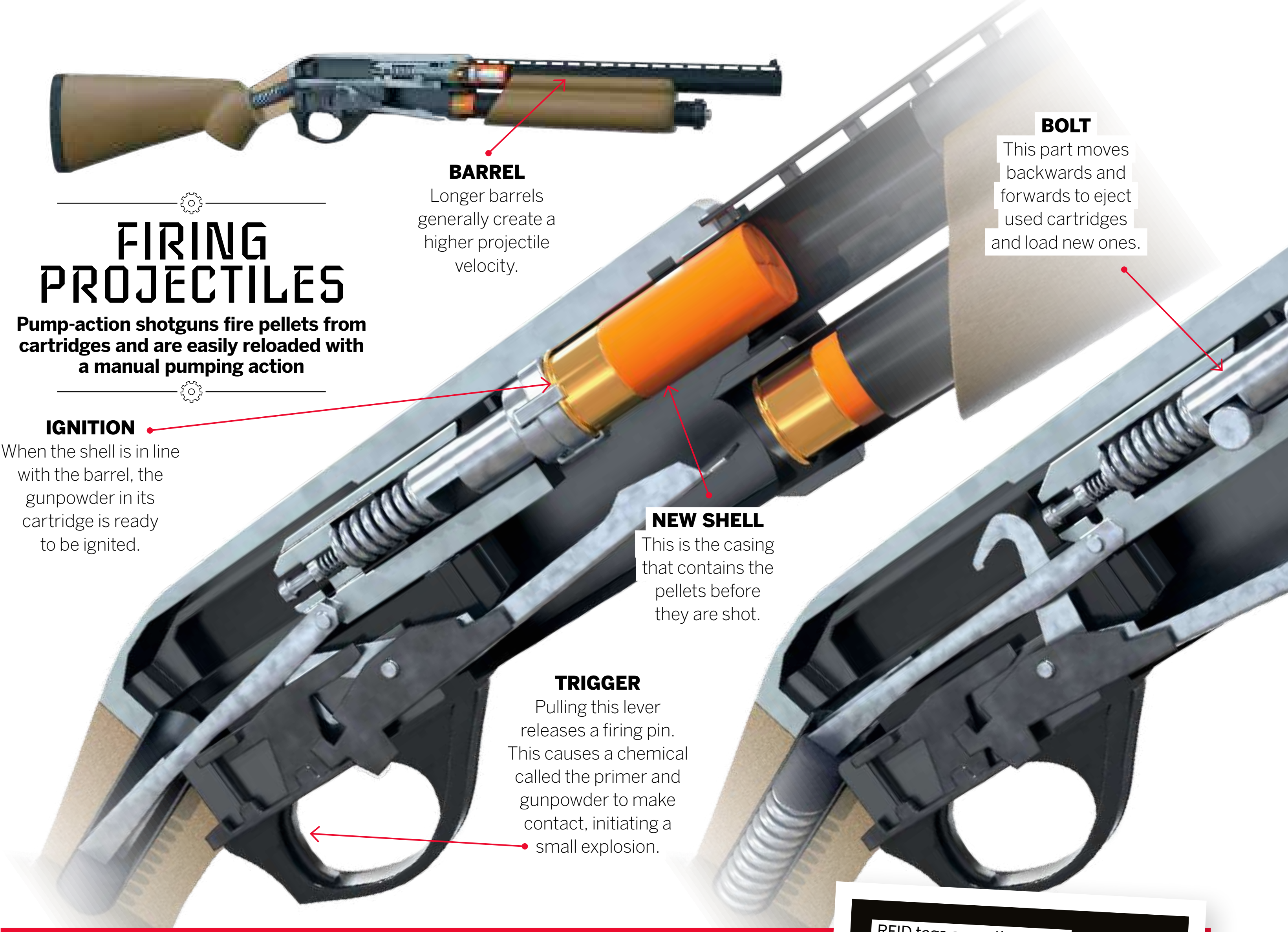
1540

The principle of rifling, which involves spinning the projectile, was first put into practice.

© Getty / Wiki: Violett-le-Duc

FIRING PROJECTILES

Pump-action shotguns fire pellets from cartridges and are easily reloaded with a manual pumping action



BARREL
Longer barrels generally create a higher projectile velocity.

BOLT
This part moves backwards and forwards to eject used cartridges and load new ones.

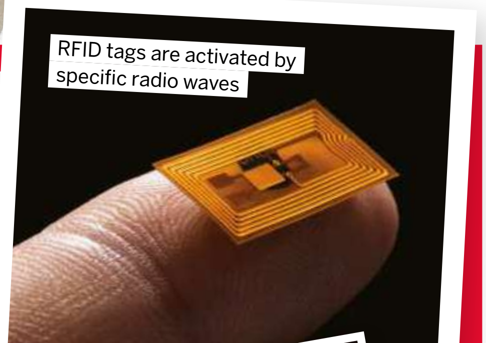
IGNITION
When the shell is in line with the barrel, the gunpowder in its cartridge is ready to be ignited.

NEW SHELL
This is the casing that contains the pellets before they are shot.

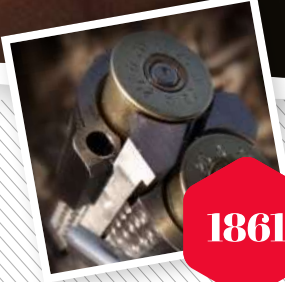
TRIGGER
Pulling this lever releases a firing pin. This causes a chemical called the primer and gunpowder to make contact, initiating a small explosion.

SMART GUN TECHNOLOGY

Guns are dangerous, especially in the wrong hands. One way to reduce accidental or criminal shootings is the introduction of smart guns. This technology uses radio frequency identification (RFID) and biometric technology. The former prevents unauthorised users from shooting a gun, as it remains locked until the owner is within close proximity. Biometrics use information such as fingerprints to unlock the weapon. The manufacturers of these guns believe that extra security will prevent thousands of lives from being lost each year, while others argue that it contributes to a greater issue of gun availability.



RFID tags are activated by specific radio waves



1750

Duelling pistols became popular. These were 23 to 25 centimetres long and barrelled.

1776

Great Britain's 13 American colonies fought a war for independence. More factories producing firearms emerged in the US during the American Revolution.

1850

Modern shotguns were produced, becoming popular in the second half of the 19th century.

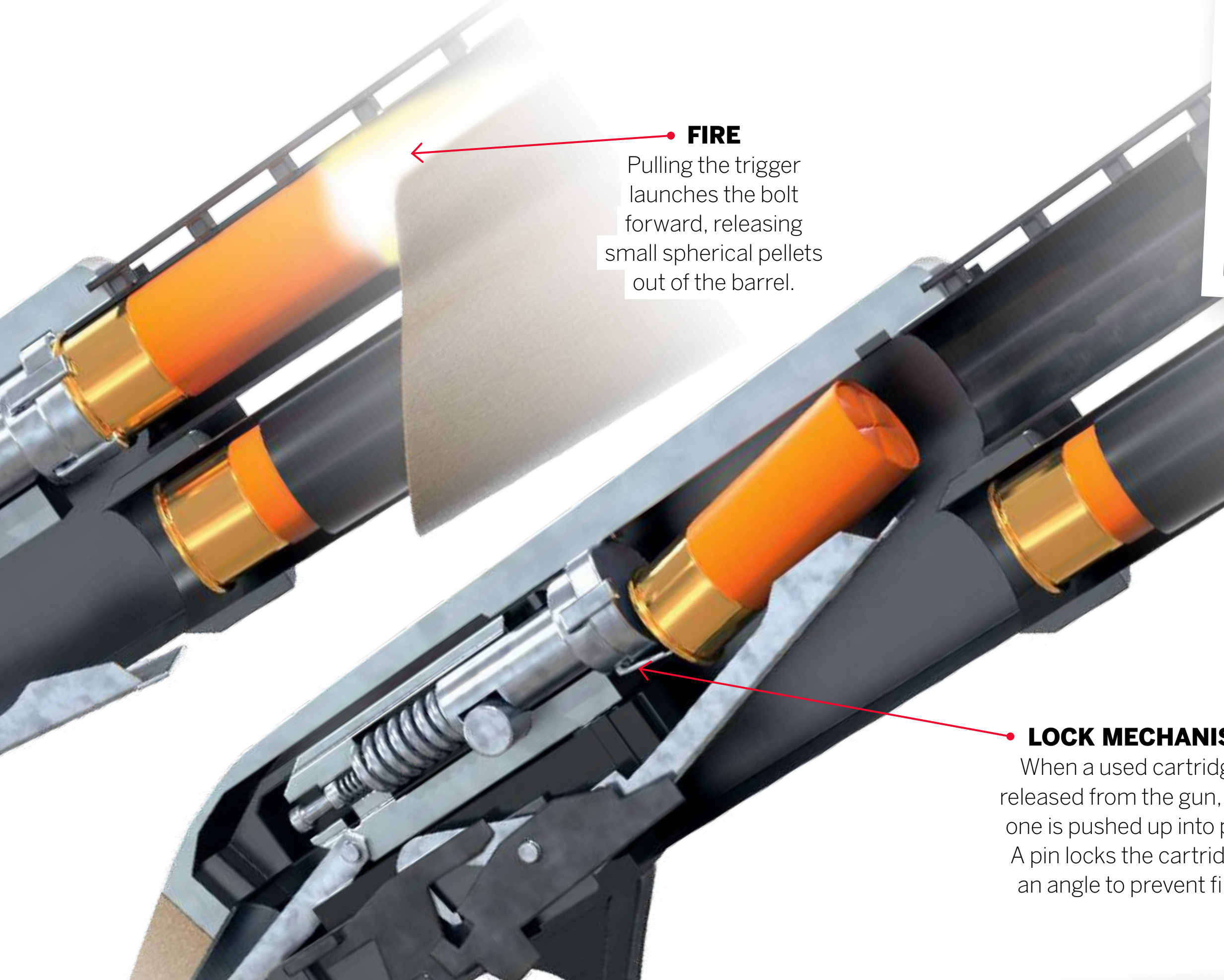
1853-56

The Crimean war was the last war in history to use muzzle-loaded firearms – those loaded through the front of the gun.

1861

Breech-loaded guns, which loaded cartridges at back of the gun, became popular.

DID YOU KNOW? The world's oldest surviving firearm, the Heilongjiang hand cannon, was made in 1288



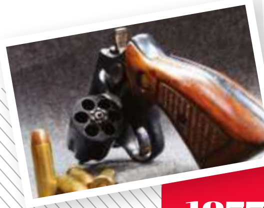
FIRE
Pulling the trigger launches the bolt forward, releasing small spherical pellets out of the barrel.

LOCK MECHANISM
When a used cartridge is released from the gun, a new one is pushed up into place. A pin locks the cartridge at an angle to prevent firing.

Shooting ranges offer target practice

Blinders help with accuracy

Did you know?
Gunpowder arrived in Europe in the 13th century



1872

Colt's Single-Action Army 'Peacemaker' was developed, later adopted by the US Army until 1892.

1877

The first successful dual-action revolver was produced. This rotated the cartridge holder, or cylinder, into position and fired a bullet in one pull of the trigger.

1892

The first automatic handgun was created by Austrian inventor Joseph Laumann.

20th century

The 1900s saw a meteoric rise in gun ownership in the US. By the turn of the millennium, nearly 40 per cent of US households owned one or more firearms.

5 SHOOTING SPORTS CATEGORIES

1 BULLSEYE
Sports in this category include a target. Competitors aim for the centre of the target to gain the most points.

2 LONG-RANGE
In these sports, the distance between the shooter and the target is hundreds of metres. This means that gravity, wind speed and direction all need to be considered.

3 RAPID FIRE
Using handguns, competitors are given just a few seconds to fire five successive shots at a target.

4 CLAY TARGET
This sport tests the shooter's ability to hit fast-moving targets. Clay targets are fired through the sky, and competitors take it in turns to shoot several per round.

5 MULTI-SPORT
For some events, shooting is just one sport among several. For example, in a biathlon athletes compete in cross-country skiing with shooting zones spread throughout the course. Athletes need to steady their heart rate before picking up the rifle to ensure they hit the targets.

© Getty

INSIDE A DSLR CAMERA

How these digital cameras use a mirror and a prism to take a picture

WORDS **SCOTT DUTFIELD**

The digital single-lens reflex (DSLR) camera brought about a revolution in digital photography. As the next stage in the evolution of photographic technology, DSLR cameras offered a digital alternative to professional photography. As the name suggests, DSLRs use a single lens, typically detachable, which directs light to a digital image sensor. The image captured by the sensor is then projected onto an LCD screen or an electronic viewfinder. En route to the image sensor, light is interrupted by a mirror, which sends it upwards into a prism sitting behind the viewfinder. Once the light hits the prism, it's redirected into the viewfinder so the photographer can see what they want to capture.

When the trigger is pressed, both the internal mirror and a shutter that conceals the image sensor quickly retract, temporarily allowing light to directly hit the sensor before returning to their place. This mechanical reflex is also what gives the camera its iconic snapping sound. Before DSLRs took photography digital, SLRs used the same interior mechanics as their digital remakes, but rather than using an image sensor, cameras relied on light exposure to a reactive film that was later developed into print photographs. When the millions of pixel cells that make up a digital image sensor are exposed to light, the light is turned into electrical signals. These signals are translated by the camera's built-in processor, which creates the final image and displays it on a rear LCD screen.

Did you know?
In 2021, 2.16 million DSLR cameras were shipped worldwide

CONTROLS
As a digital camera, there are many automatic presets for levels of aperture, exposure and focus.

LCD SCREEN
DSLRs benefit from digital displays to instantly preview an image that's been captured on the image sensor.

MENU
OK
AE-L AF-L

THE FIRST SHOT

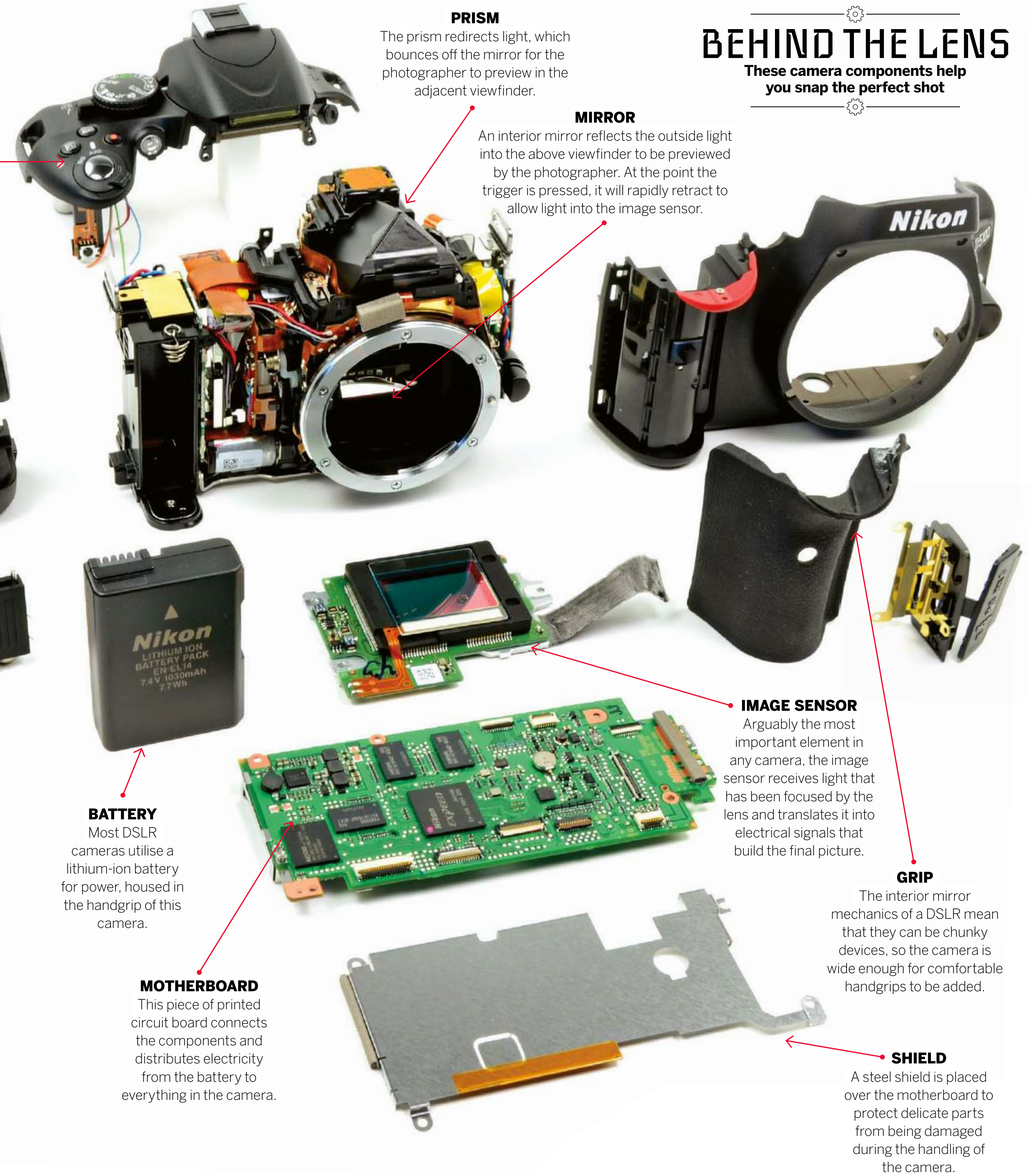
On 15 June 1999, Nikon announced that it had created its first practical DSLR camera. Boasting 2.7 megapixels, the D1 paved the way for digital photography. With a price tag of around £4,300 ($6,200) the D1 was an investment, one that many newspapers made by ditching their old physical film cameras. Although the D1 is more of a museum exhibit than a working camera, at the height of its popularity it boasted some impressive specs. The D1's top shutter speed – the length of time the image sensor shutter is open – is 1/16,000th of a second, which is superfast when you consider many modern-day DSLR shutter speeds top out at 1/8,000th of a second.

The D1 by Nikon – its first DSLR camera

DID YOU KNOW? The camera was invented in 1816 by French inventor Joseph Nicéphore Niépce

BEHIND THE LENS

These camera components help you snap the perfect shot



PRISM
The prism redirects light, which bounces off the mirror for the photographer to preview in the adjacent viewfinder.

MIRROR
An interior mirror reflects the outside light into the above viewfinder to be previewed by the photographer. At the point the trigger is pressed, it will rapidly retract to allow light into the image sensor.

IMAGE SENSOR
Arguably the most important element in any camera, the image sensor receives light that has been focused by the lens and translates it into electrical signals that build the final picture.

BATTERY
Most DSLR cameras utilise a lithium-ion battery for power, housed in the handgrip of this camera.

GRIP
The interior mirror mechanics of a DSLR mean that they can be chunky devices, so the camera is wide enough for comfortable handgrips to be added.

MOTHERBOARD
This piece of printed circuit board connects the components and distributes electricity from the battery to everything in the camera.

SHIELD
A steel shield is placed over the motherboard to protect delicate parts from being damaged during the handling of the camera.

© Getty / Wiki: Ashley Pomeroy / iFixit.com

Win!

ONE OF TEN BUILD YOUR OWN PINBALL MACHINE KITS

This month we're giving you the chance to win one of ten Build Your Own Pinball Machine kits. These STEAM-inspired toys are fun for the whole family and are made from eco-friendly cardboard parts that fit together without the need for additional glue or adhesives. With only an hour of build time, you'll be whizzing marbles around the pinball machines' vibrant design before you know it

PINBALL MACHINE
PINBALL
OUT

For your chance to win, answer the following question:

How many horns does a triceratops have?

A: THREE B: FOUR C: ONE

Enter online at **howitworksdaily.com** and one lucky entrant will win!

Terms and Conditions: Competition closes at 00:00 BST on 26 October 2022. By taking part in this competition you agree to be bound by these terms and conditions and the Competition Rules: **www.futuretcs.com**. Entries must be received by 00:00 BST on 26/10/2022. Open to all UK residents aged 18 years or over. The winner will be drawn at random from all valid entries received, and shall be notified by email or telephone. The prize is non-transferable and non-refundable. There is no cash alternative.

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Why doesn't alcohol freeze in the freezer?

Stu Talbot

The type of alcohol that people can drink is called ethanol, which has a freezing point of -114 degrees Celsius – much lower than a domestic freezer can reach. However, ethanol is always mixed with water and other flavourings before being drunk, raising the melting point. The amount of ethanol in a drink is described as the percentage alcohol by volume (ABV). The freezing point of a particular drink depends mainly on the percentage of ethanol in it: the higher the percentage of alcohol, the lower the freezing point. This means it's unlikely that you could freeze vodka, gin or whiskey in a domestic freezer. Beer and wine, however, have a lower percentage of alcohol and so can sometimes be frozen. A lot depends on the freezer. Domestic freezers tend to work at around -20 degrees Celsius, but this can vary enormously.

Did you know?
Modern domestic freezers were introduced in 1927

WHY DOESN'T THE ICE CREAM IN A BAKED ALASKA MELT?

Sue Connelly

Baked Alaska is a dessert in which fruit and ice cream are put in a sponge flan base and topped with meringue. The whole thing is then baked in the oven at a high temperature for a few minutes. If it comes out right, the meringue is hot and the ice cream is still frozen.

The key to successful Baked Alaska is ensuring there are no gaps in the meringue. The meringue – and to a certain extent the sponge – insulates the ice cream from the heat of the oven. Meringue is a particularly good thermal insulator because whipping the egg whites fills them with lots of air, and any layer with a lot of trapped air is a poor conductor of heat. Heat from the oven would get through eventually, but the short cooking time means there just isn't enough time for this to happen.

HOW DOES HAIR DYE WORK?

Nathalie Pate

Hair strands have three layers: the outer layer is the cuticle, the middle layer is the cortex and the inner layer is the medulla. The cuticle is hard and transparent and the cortex contains melanin, which gives hair its colour. The large molecules in temporary hair dyes only penetrate the cuticle, so they don't change the colour of your hair – they just colour the outside and then wash out. Semi-permanent hair dyes have colouring agents with small molecules that pass through and sit just under the cuticle. Demi-permanent hair dyes have molecules that bond with preexisting hair molecules, so survive a lot more washes. Permanent dye, meanwhile, opens the cuticle and has ammonia and peroxide that react with molecules in your hair to change its colour.

Did you know?
Camels have three sets of eyelids

WHY DO CAMELS HAVE HUMPS?

Danielle Bainbridge

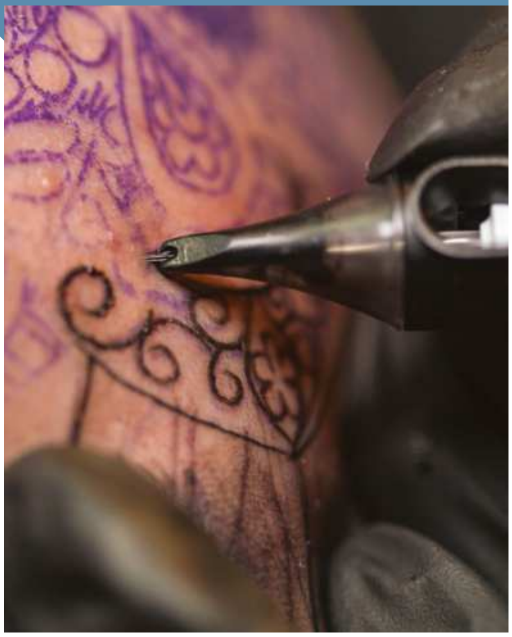
Camels live in environments where food and water can be scarce, so they frequently go for long periods of time without eating or drinking. Camel humps are full of fat that they use for energy when they don't have any food or water. Most animals have fat spread around their body, which is useful for animals like polar bears as they live in a really cold environment and the thick layer of fat around their body helps. With camels, all their fat is on their backs to avoid excess body heat. When all the fat has been used in a camel hump, it becomes floppy and hangs to one side.

How does freeze drying work?

Tom Carter

Freeze drying is a process that's mainly used to preserve food. It works by removing water from the substance to be preserved so microorganisms that cause food and other substances to spoil cannot survive. The key principle behind freeze drying is sublimation. This occurs when a substance changes straight from a solid to a gas, missing out the liquid phase altogether. To use the substance, simply add water and it will return to its original state. Heating it gently ensures that the substance is not damaged or changed in the process.

© Getty



WHY DOESN'T A PERMANENT TATTOO RUB OFF?

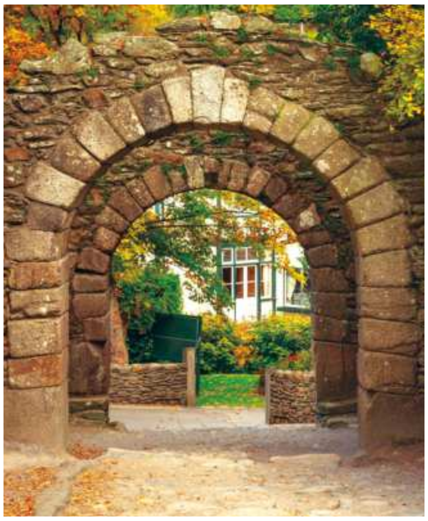
Nick Little

The skin has two main parts: the epidermis and the dermis. The thinner outer layer is called the epidermis and it's constantly shedding and replacing itself. Injecting ink, or pigment particles, into the dermis, which is located beneath the epidermis, produces a permanent tattoo. During the process, the epidermis and the dermis are damaged. Although initially some ink may be removed by cells of the immune system, as the skin begins to heal, the majority of the ink is trapped in the upper layers of the dermis. This is due to cells called fibroblasts and the formation of connective tissue. The ink is located in the dermis at a depth of one to three millimetres, and we view the tattoo through the translucent epidermis. Tattoos won't rub away, but they do begin to fade with age. This fading may be due to the ink moving down to deeper layers of the dermis, and some suggest that some ink may be removed by the lymphatic system.

WHY ARE ARCHES SO STRONG?

Alex Wu

Arches are very strong because they transfer the weight upon them horizontally, and each section of the structure diverts a portion of the load into its neighbouring section. This means that the load placed upon the bridge is evenly spread throughout, with the downward-acting force distributed into the abutments – the arch's supports, which are commonly placed either side – and into the ground, or into the ground directly and absorbed. As stone and brick are strong in compression, any arch constructed out of them is constantly under compression due to the force of a bridge's load emanating constantly out from its central keystone. In essence, this means that within the tolerance of the material, the more load put onto an arched structure, the stronger it becomes.

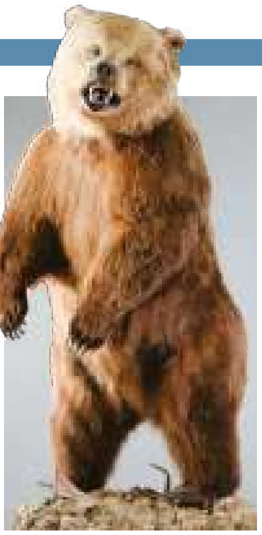


Why does human hair turn white?

Bryan Webb

Human hair is actually white to begin with. Melanin is the biological pigment that gives our hair and skin their colour. The formation of melanin begins before we're born, giving us our natural hair colour. As we age, the cells that produce melanin begin to deplete. As the melanin in our hair starts to reduce, our hair turns grey, and when it completely runs out it turns white again.

Did you know?
Black is the most common natural hair colour



HOW ARE ANIMALS STUFFED?

Paul White

The process of stuffing animals is also known as taxidermy. Taxidermy has been used for around 400 years to preserve deceased animals as trophies or for historical and educational purposes. To start, the taxidermist removes the skin of the animal. This is a painstaking process, as all the flesh that will decompose is removed while attempting to leave the skin as intact as possible. Depending on the species, different chemicals and salt can be applied to preserve and soften fur, feathers or scales. Then the artificial body of the animal is made. The techniques used are species dependent. Often the carcass is used as a mould or mannequins are made from polyurethane foam. The treated skin is then carefully placed onto the artificial body. Taxidermy techniques have changed slightly over the years; some modern taxidermists have started to develop freeze drying, which won't involve any stuffing at all.

© Getty

What are antlers made of?

Kim Blake

Antlers are the large bony appendages found on the heads of most male deer species. They start life as spongy tissue which gathers minerals and becomes hard bone. The spongy tissue and then bone are covered by a layer of skin called velvet, providing blood to deliver oxygen and nutrients to the antlers. Once an antler has grown to its full size, the velvet falls or is rubbed off and the bone dies, forming the mature antler. This mature antler will eventually fall or be broken off and be regrown each year. Antlers are different from horns, which are made of keratin layered over bone and grow continuously.

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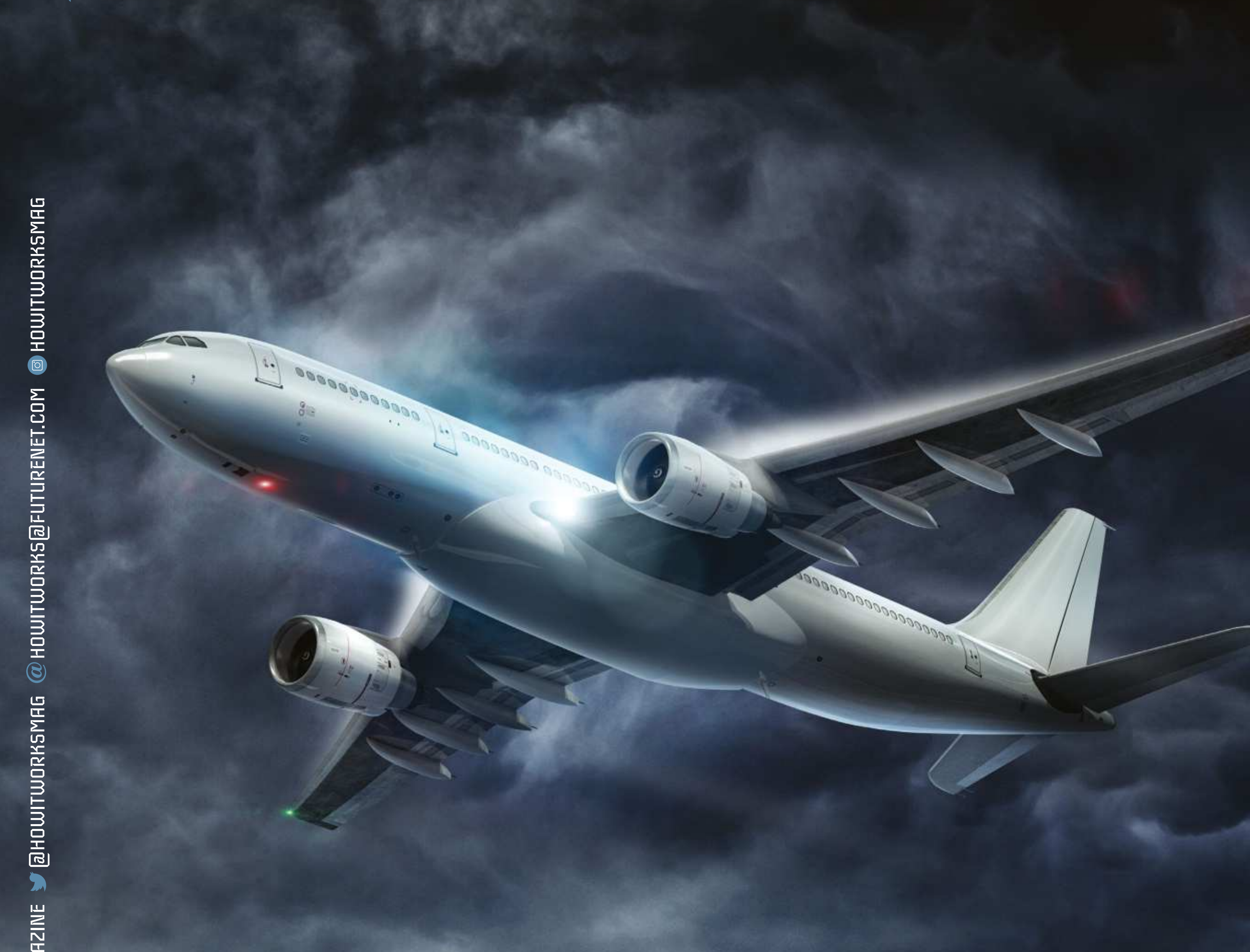

What is air turbulence?

Lorna Patel

Many of us have experienced some form of turbulence while on a flight, and it's caused by the irregular movement of air. As different pressures or streams of air collide, they create movement waves. When flying through these waves, it causes the plane to bounce around. Causes of turbulence can be airflow over mountains, heat convection currents, updrafts and downdrafts in clouds, thunderstorms and, in high altitudes, vertical winds, and it's found most commonly in jet streams.

WHAT'S THE OLDEST FOSSIL EVER FOUND?

Steven Thorne

The oldest fossils found are stromatolites. It's thought that the oldest were discovered in Australia and are nearly 3.5 billion years old. Stromatolites were formed by the activity of ancient microorganisms, primarily cyanobacteria. The photosynthetic activity of these early life forms caused a reduction in the carbon dioxide present in the surrounding water. This drop in the acidity of the water caused calcium carbonate to be deposited. Calcium carbonate and other sediments from the water were then trapped in the sticky layer of mucilage that surrounds bacterial colonies. Over time the bacterial colonies grew and layer upon layer of sediment built up, leaving behind these ancient stromatolite structures. They provide us with a valuable record of early life on Earth.

WHAT ARE OUR FINGERNAILS MADE OF?

@closetgeek

Fingernails are made of a tough protein called keratin, from the Greek word 'kera', meaning horn. Keratin is also what animals' hooves and horns are made from. Most animals have a supportive bone structure in their horns, although rhinoceros horns are made completely of keratin compacted together. The only other biological material which has a similar toughness to keratinised tissue is chitin, the main component of exoskeletons belonging to arthropods.

The crescent shapes that you can see at the bottom of your nails are called lunulae. These are groups of cells that produce keratin and other living cells. As these living cells are pushed forward by newer cells, they die and merge with the keratin to become keratinised. They then become flattened, stiff and known as your fingernails.

Did you know?
Elephant tusks are more like teeth than horns

WHAT ARE NOSEBLEEDS AND WHAT CAUSES THEM?

@cjayp33

The medical term for nosebleeds is epistaxis – when the tiny blood vessels in your nose bleed. Several a week may be attributed to factors such as high blood pressure. 90 per cent of epistaxis occurs in the Kiesselbach's plexus, or Little's area, a region in the nose where five arteries join together. The position of this means that it's largely affected by breathing and dries out, making the mucous membrane in your nostrils become inflamed or cracked and more likely to haemorrhage.

Why is urine sterile?

Alec Gardner

Urine is the body's way of removing toxins and waste from the blood. It's secreted by the kidneys, stored in the bladder and leaves the body via the urethra. The kidneys are essential in filtering out toxins that could build up in the blood and are very good at it. Assuming a person is healthy, their urine will be sterile when it leaves the body. If the urine is left alone, bacteria may develop in it. Freshly passed urine from a healthy body can sometimes be safe to drink – in fact, doctors even used to test urine by tasting it.

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THE LIBRARY

The latest book releases for curious minds

PLANET-FRIENDLY HACKS

SAVE MONEY, SAVE THE PLANET

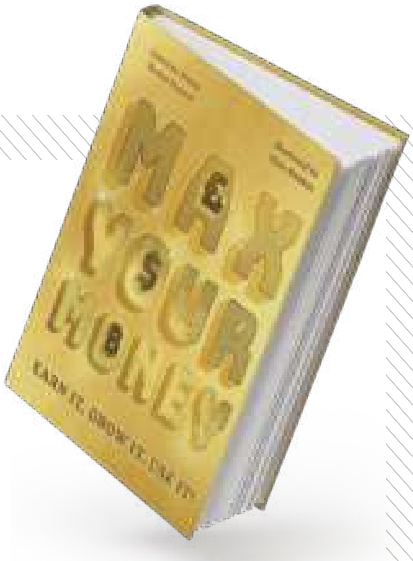
AUTHOR **ELIZABETH AJAO**
ILLUSTRATOR **JULIE GOLDSMITH**
PUBLISHER **OCTOPUS PUBLISHING GROUP**
PRICE **£9.99 (APPROX. $11.55)**
RELEASE **OUT NOW**

Planet-Friendly Hacks
Simple Tips and Budget-friendly Advice for Sustainable Living
Elizabeth Ajao

In 1861, *Mrs Beeton's Book of Household Management* was published to roaring success. Packed with recipes, tips and tricks for managing a quintessential Victorian household, it became a bestseller practically overnight, with dozens of new editions published over the next 150 years. We're not making a direct comparison between *Planet-Friendly Hacks* and a vintage cookbook containing the likes of beef wellington and suet pudding recipes, but there's something about the rustic 19th-century ethos that rings true here: it's an era before society got thoroughly addicted to cheap mass production and industrial chemicals, when people turned to homespun solutions that called largely for the use of natural ingredients and leftovers, not because they were trying to reduce their carbon footprint, but because that was their only choice.

Elizabeth Ajao's book of sustainable living has the same kind of domestic alchemy about it that made Mrs Beeton's so popular, but taps into the eco-conscious zeitgeist of the 21st century. With everything from kitchen cleaning hacks and simple meals to DIY and gardening, there are dozens of practical and cost-effective alternatives to off-the-shelf products: home-made whitening toothpaste, carpet cleaners, tips for a more sustainable wardrobe, upcycling ideas, vertical gardens and more – all designed to maximise your wallet, minimise waste and eliminate toxic chemicals, plastics and other environmental nasties. It's not all lemon juice and bicarbonate of soda, although these ingredients are very common in alternative cleaning products. *Planet-Friendly Hacks* includes ideas for attracting insects that will act as natural pest controllers or pollinators in your garden, like lacewings and bees. There's a section on eco-conscious travelling, too, although this feels like a smaller afterthought to the extensive and comprehensive compendium of home solutions that make up the rest of the book. With the UK and many other countries heading into the thick of a cost-of-living crisis, adopting the routines and recipes here could be a good way to cut bills, let alone help save the planet.

> **"Routines and recipes here could be a good way to cut bills"**



MAX YOUR MONEY

EARN IT, GROW IT, USE IT

AUTHOR **LARRY HAYES AND RACHEL PROVEST**
PUBLISHER **WELBECK PUBLISHING GROUP**
PRICE **£14.99 / $16.95**
RELEASE **OUT NOW**

When should children start to think about their financial futures? If you're a parent wondering about this very question, it's likely time to hand them a copy of this brilliant practical guide. From the basic understanding of how money works to the implications of investments, future career prospects and financial management, *Max Your Money* leaves no stone unturned when it comes to understanding the world of money. Each of the pages in this illustrative guide is populated with insightful nuggets of information in small boxes. So often books that cover financial management lack the ability to grip a younger audience long enough for them to learn anything. That's not the case with *Max Your Money* thanks to its vibrant graphics, illustrations and concise statistics. It's a book that as an adult we wish we had read as a teenager and kept with us as we entered adulthood.

THE ANIMAL ADVENTURER'S GUIDE

50 ACTIVITIES TO GET WILD WITH ANIMALS

AUTHOR **SUSIE SPIKOL**
ILLUSTRATOR **BECCA HALL**
PUBLISHER **SHAMBHALA**
PRICE **£14.99 / $17.95**
RELEASE **OUT NOW**

If you're a young adventurer wanting to explore more of the wildlife and nature around you, this book will provide you with many new ideas and activities. Whether you're into bird life, mammals, arthropods, reptiles or other invertebrates, you will find the perfect animal-based activity for you within this guide. The best way to find and observe different species is to know where they live, how to approach them and what times give you the best shot at a close encounter. This book is filled with top tips, helpful facts and comes with a different checklist of objectives and outcomes for every activity. Bird lovers can enjoy making their own bird feeder and secret hide to birdwatch from, while the instructions to make a bait-filled footprint tracker will leave mammal-spotters amazed by the nighttime activity they reveal.

As well as bringing readers closer to various animals, *The Animal Adventurer's Guide* explains how different creatures navigate the world with engaging activities. You can learn how to smell with your tongue just like a snake, speak a secret bird language and navigate by nose just like a wolf. When flicking through this book, it will be difficult not to find something that piques your interest or makes you want to run straight outside.

WHEN I'M AN ASTRONAUT

INSPIRATIONAL CAREERS FOR KIDS

AUTHOR **SAMANTHA PILLAY**
ILLUSTRATOR **HARRY AVEIRA**
PUBLISHER **SAMANTHA PILLAY**
PRICE **£15.99 / $18.99**
RELEASE **OUT NOW**

The dreams of young children are greatly shaped by what they are taught about and exposed to. Quite often, children are less aware of the vast possibilities available to them in STEAM. This book is one in a series explaining some of the key qualities and activities involved in these diverse professions. The large illustrations in this book depict the truly fascinating and unique nature of a job away from Earth. Each volume in the series follows a character with different characteristics, and this one features a young girl. Exploring the life of an astronaut through the dreams of a female main character achieves a vital purpose in preventing the long-held association of astronauts being solely male. The book helps anyone with an interest in space to imagine themselves in that role too.

When I'm an Astronaut includes an appropriate balance of detailed aspects of the job with simplistic descriptions written in a way four to eight year olds can understand. It mentions the core subjects used in astronaut training that they will recognise from school, presents illustrations of the underwater exercises that astronauts perform in pools on Earth, spacewalking and even walking on Mars, opening their eyes to the possibilities their future holds. Any young reader will benefit from reading the books in this series to formulate their own dreams through a light-hearted and visual story.

LIGHTBULB MOMENTS IN HUMAN HISTORY

FROM THE CAVE TO THE COLOSSEUM

AUTHOR **SCOTT EDWIN WILLIAMS**
PUBLISHER **CHRONOS BOOKS**
PRICE **£17.99 / $27.95**
RELEASE **OUT NOW**

Unlike other books that offer up humanity's achievements in a top-ten fashion, *Lightbulb Moments in Human History* is written in a continual narrative from the witty and humorous perspective of its author. As the title suggests, you can expect to discover some of the many milestones that define humankind, from the Neolithic Revolution of early agriculturists to the rise of the Roman Empire. You'll also explore some of the concepts that shaped human lives, such as religion and misguided medicine. In keeping with Scott Williams' humour, which leans towards an adult audience in parts, throughout each chapter are amusing meme-style images to add further levity to the eccentricities of humankind. Wit aside, this book is expertly written and packed with interesting information and educational insight into the past. Whether you're a history buff or looking to expand your historical horizons, this book is a great read.

BRAIN GYM

Give your brain a puzzle workout

Sudoku

Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9

EASY

3	8							
4	1	6	3		9	7	5	
7		2				8	3	6
		4	5	3				8
2				7	8	5		
	6						9	7
		7	8	1		9	4	3
8	5					2	7	
	4	9		2		6		5

MEDIUM

7					1			2
5					2	7		8
		8			5			
1	4			2		3		6
3			6	5		2		
	9			7				
2	1			8	7			
		6	2			5	8	
8			4		6	9	2	

HARD

		4					2	
8				7				
	2		6	1		5		
	8			4		9	1	3
	3							7
	5		8	3				
2		7					8	
					9			
			5		3	7		6

Word search

Find the following words

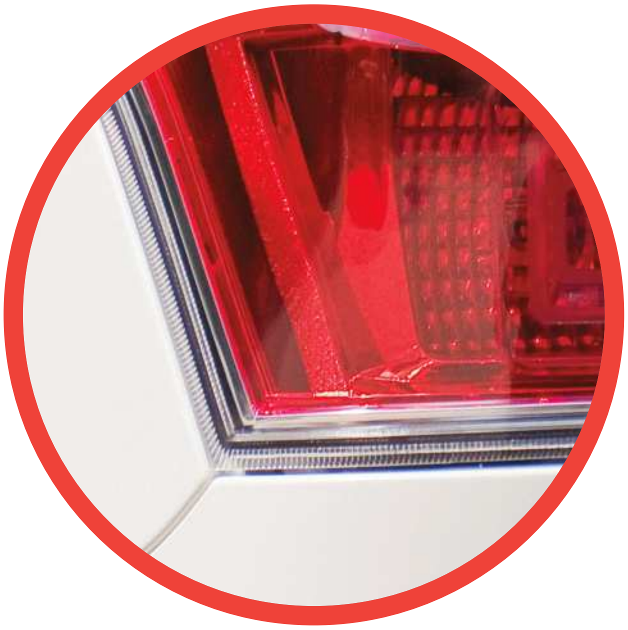
DINOSAUR
CHAIN
PLUTONIUM
GUN
SALT
COW
STARS
BENIN
PET
BALLOON
CAMERA
VEHICLE

C	U	N	B	O	L	B	E	M	I	N	V	A	H	G
O	H	W	A	S	T	A	R	S	U	P	J	O	P	B
M	U	A	D	I	N	Q	S	A	R	U	K	O	L	E
P	E	B	I	D	B	A	L	L	O	O	N	J	U	R
I	Y	P	H	N	I	N	E	D	V	E	H	E	T	O
G	U	E	C	L	E	C	A	M	E	R	S	A	O	P
E	S	T	A	Z	E	B	G	O	R	N	E	S	N	C
D	I	M	C	O	O	L	L	U	R	A	B	O	I	T
C	A	M	E	R	A	R	A	G	N	U	L	F	U	H
J	A	B	U	N	E	S	P	E	V	E	H	I	M	B
W	I	G	U	M	O	C	T	S	A	N	P	E	M	O
O	W	U	A	N	Y	X	L	O	P	D	I	N	Q	U
C	O	M	I	Z	E	B	I	K	L	M	O	N	E	Z
H	F	D	A	O	S	A	L	T	N	I	B	A	E	L
V	E	H	I	C	L	E	B	A	L	O	L	F	D	B

What is it?

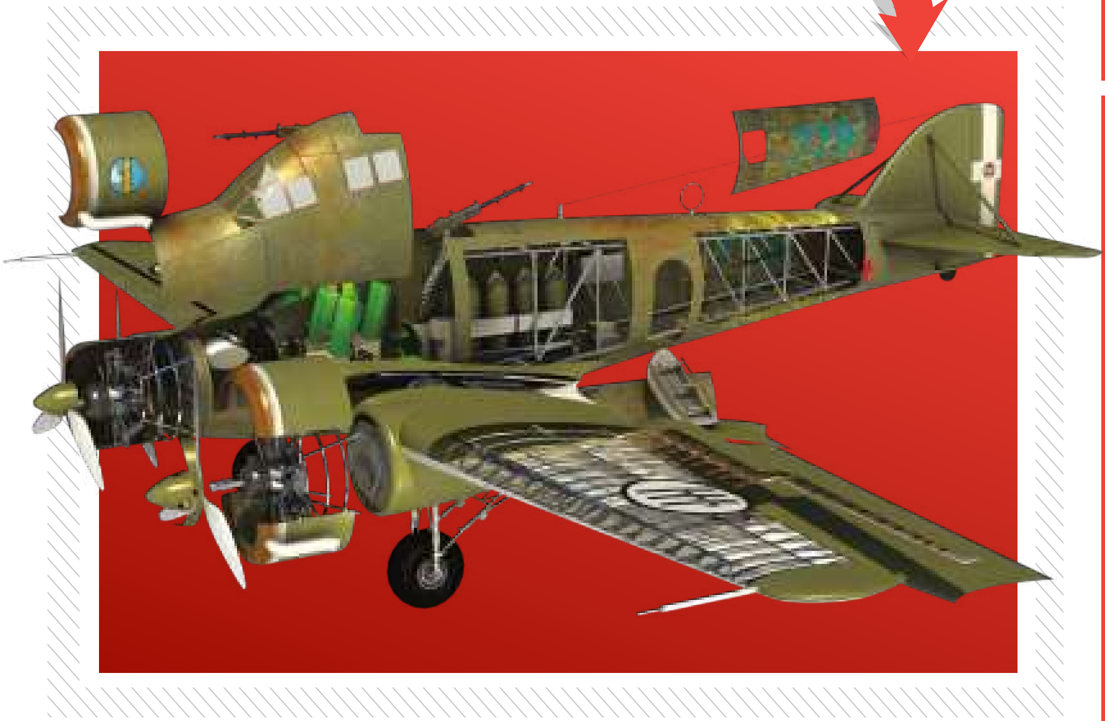
Hint: Time to slow down

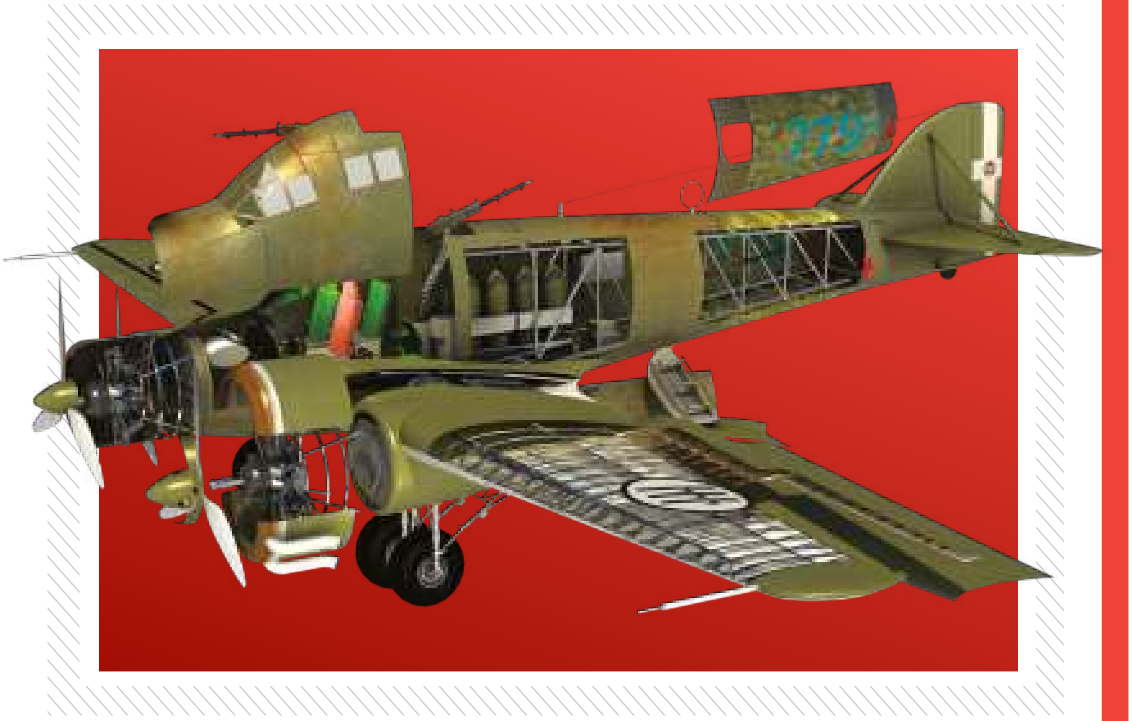
A



Spot the difference

See if you can find all six changes between the images below

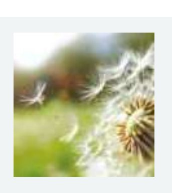




Answers

Find the solutions to last issue's puzzle pages

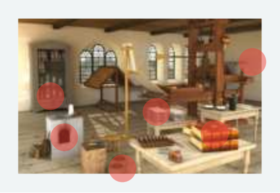
Q1 MERCURY
Q2 STARFISH
Q3 WEAK FOUNDATION
Q4 FLY
Q5 $1,000,000
Q6 COAL



What is it?

DANDELION FRUIT

Spot the difference



QUICKFIRE QUESTIONS

Q1 The world's fastest elevator travels at what speed?
○ 10 miles per hour
○ 25 miles per hour
○ 36 miles per hour
○ 47 miles per hour

Q2 What's the biggest thing a blue whale can swallow?
○ A grapefruit
○ A human
○ A cow
○ A giant squid

Q3 How much water can an oyster filter every day?
○ 5 litres
○ 230 litres
○ 300 litres
○ 1,200 litres

Q4 Where can you find the world's largest active volcano?
○ Philippines
○ Italy
○ Hawaii
○ Iceland

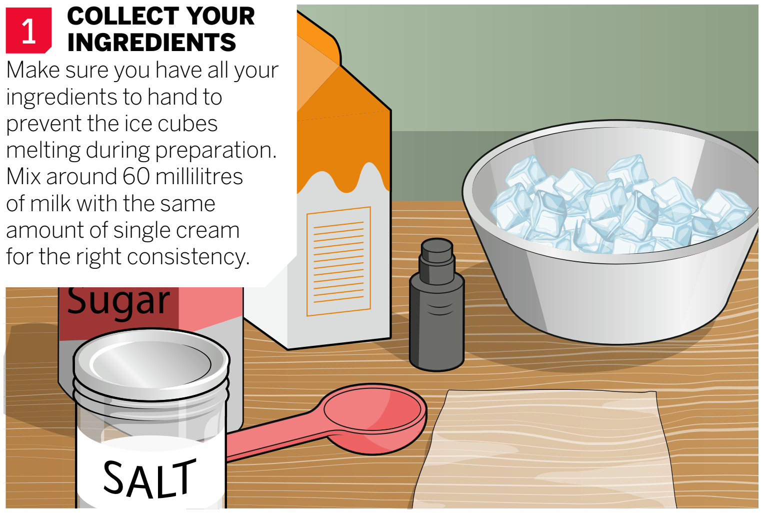
Q5 From 1912 until 1948, the Olympics awarded medals for:
○ Art
○ Woodworking
○ Beauty
○ Driving

Q6 In 1936, Russia built a computer that ran on:
○ Oil
○ Petroleum
○ Water
○ Light

© Alamy / Getty

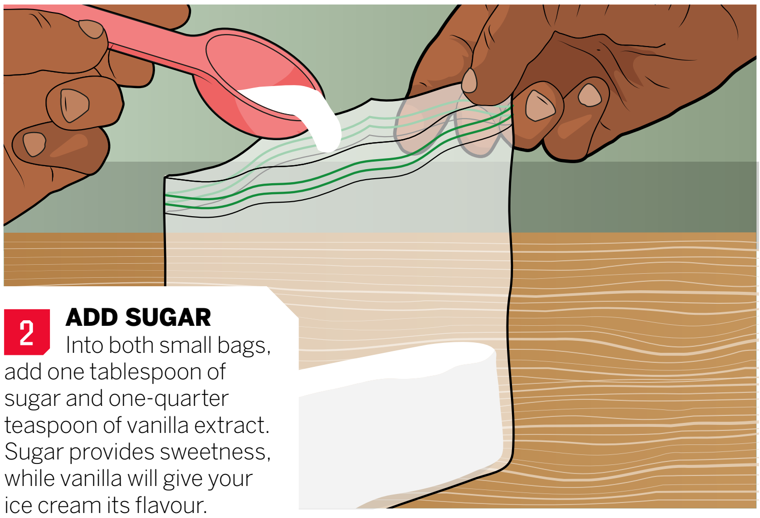
MAKE ICE CREAM IN A BAG

Following this simple recipe, your cooled snack is ready to eat in just 15 minutes



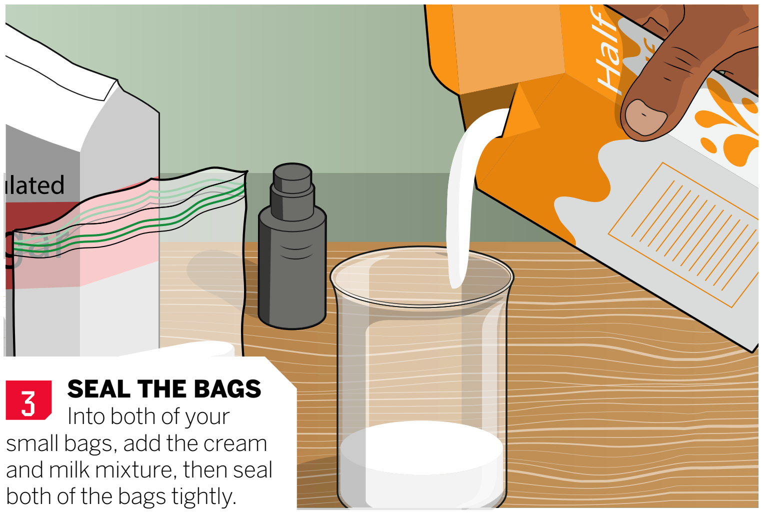
1 COLLECT YOUR INGREDIENTS

Make sure you have all your ingredients to hand to prevent the ice cubes melting during preparation. Mix around 60 millilitres of milk with the same amount of single cream for the right consistency.



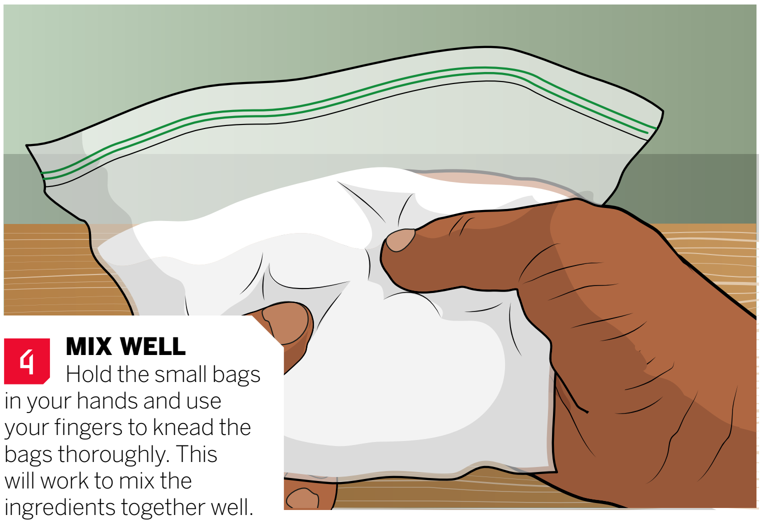
2 ADD SUGAR

Into both small bags, add one tablespoon of sugar and one-quarter teaspoon of vanilla extract. Sugar provides sweetness, while vanilla will give your ice cream its flavour.



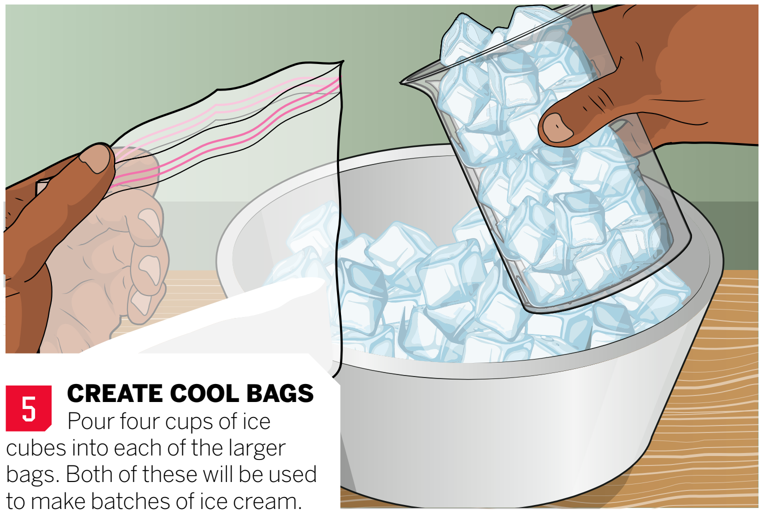
3 SEAL THE BAGS

Into both of your small bags, add the cream and milk mixture, then seal both of the bags tightly.



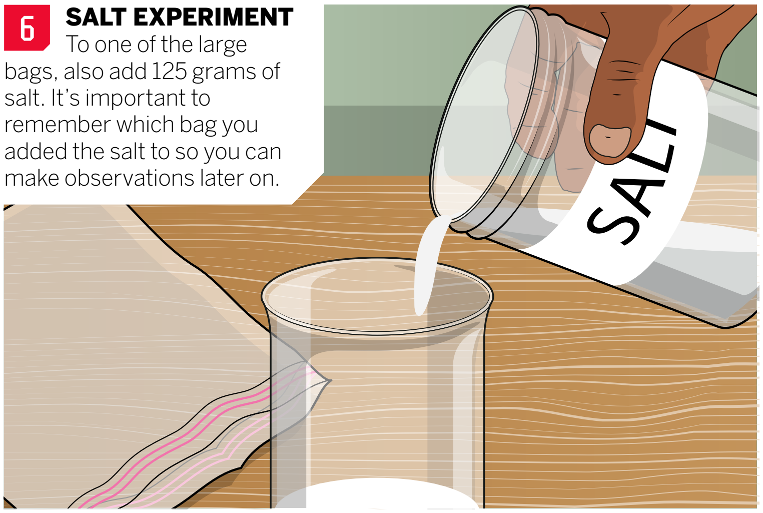
4 MIX WELL

Hold the small bags in your hands and use your fingers to knead the bags thoroughly. This will work to mix the ingredients together well.



5 CREATE COOL BAGS

Pour four cups of ice cubes into each of the larger bags. Both of these will be used to make batches of ice cream.



6 SALT EXPERIMENT

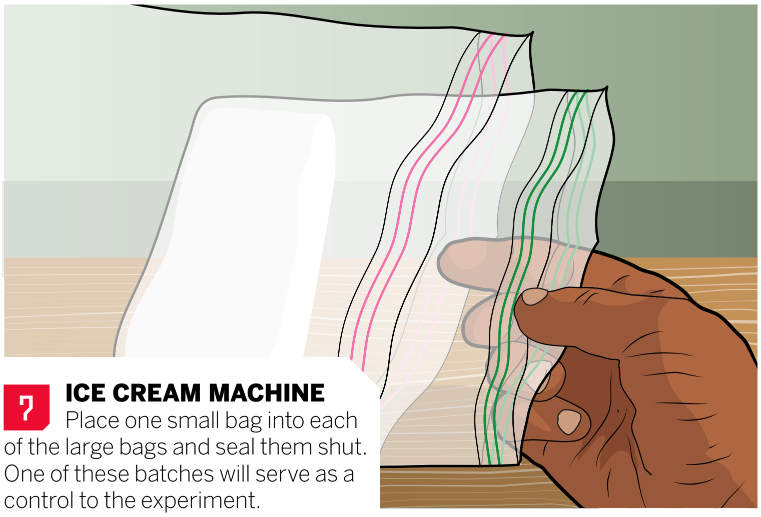
To one of the large bags, also add 125 grams of salt. It's important to remember which bag you added the salt to so you can make observations later on.

KIT LIST

- Measuring spoons and cups
- Sugar
- Single cream and milk
- Vanilla extract
- Salt
- Ice cubes
- Two small sealable sandwich bags
- Two large sealable bags
- A small towel

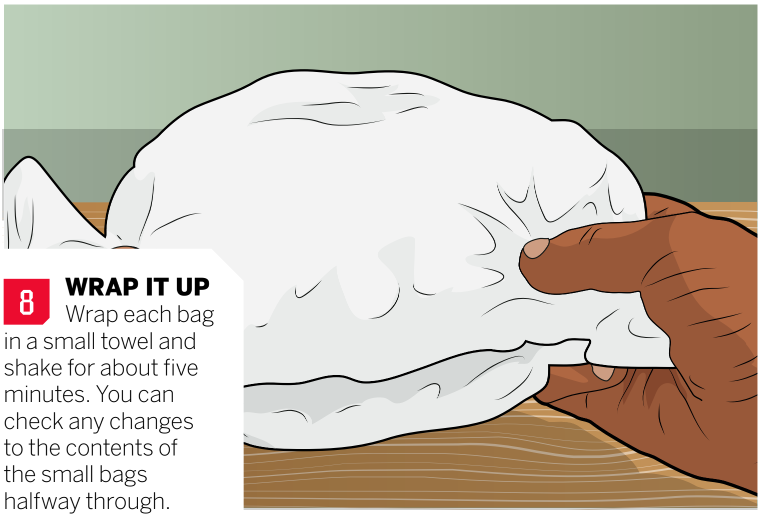
DON'T DO IT ALONE!
If you're under 16, make sure you have an adult with you

NEXT ISSUE
WEAVE YOUR OWN SPIDER WEB



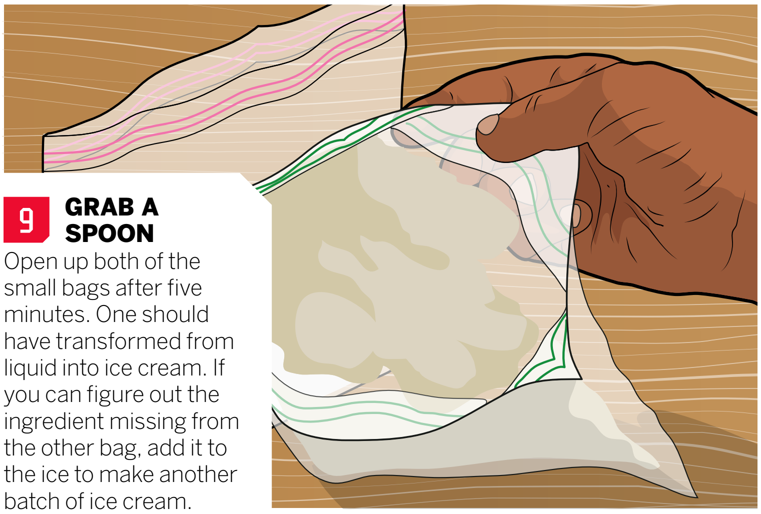
7 ICE CREAM MACHINE

Place one small bag into each of the large bags and seal them shut. One of these batches will serve as a control to the experiment.



8 WRAP IT UP

Wrap each bag in a small towel and shake for about five minutes. You can check any changes to the contents of the small bags halfway through.



9 GRAB A SPOON

Open up both of the small bags after five minutes. One should have transformed from liquid into ice cream. If you can figure out the ingredient missing from the other bag, add it to the ice to make another batch of ice cream.

SUMMARY

This is a fun experiment on a hot day – or any day for ice cream lovers – but how exactly does it work to quickly freeze the milk and cream? The salt in the large bag is a catalyst that lowers the freezing point of water to below that of the large bag with just ice cubes inside. When the temperature is low enough, the molecules in water slow down, meaning they can line up to form solid ice crystals, or ice cubes.

When they are outside the freezer and in the bag, the ice cubes will start to melt. The presence of salt prevents the water from refreezing at the surface of the ice cubes, helping to speed up the melting process. This increases the rate at which the ice cream forms because the ice absorbs the surrounding heat from the ice cream mixture as it melts. This causes the mixture to freeze, forming your ice cream in the smaller bag.

Had a go? Let us know!

If you've tried out any of our experiments – or conducted some of your own – let us know! Share your photos or videos with us on social media.

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INBOX

Speak your mind

HARDY HEATHER

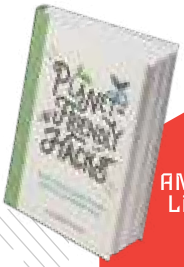
Dear **HIW**,
I read somewhere that heather is one of the toughest plants in the world. Is this true, and what makes it so tough? Also, what makes it purple?
Andrea Collins

LETTER of the MONTH

Thanks for your letter, Andrea. Heather is quite an easily recognisable plant, being covered in the small purple flowers you mention. However, it is not as widespread as you might think for a 'tough' plant. Although you're correct that it's considered one of the toughest plants, it does require some specific conditions. Heather can only grow in acidic soil with a pH between 4.5 and 6.0, but where it does grow it's relatively indestructible. Heather can grow in temperatures as low as -20 degrees Celsius and in rocky soils. Heather is known to survive frosty weather, droughts and even forest fires. During the latter, heather detects the smoke, which causes the plant to germinate. To survive burning, the seeds are highly heat-resistant.

Heather can be either white or purple in colour. Those that are purple contain the anthocyanin pigment, which can produce red, blue and purple colours in plants, while white heather is unable to produce this pigment. Anthocyanins not only give heather its attractive colour, but antioxidant qualities which scientists incorporate into some medicines.

Heather grows across Western Europe, in northeastern areas of North America and in Siberia



WIN!

AN AMAZING PRIZE FOR LETTER OF THE MONTH

PLANET-FRIENDLY HACKS

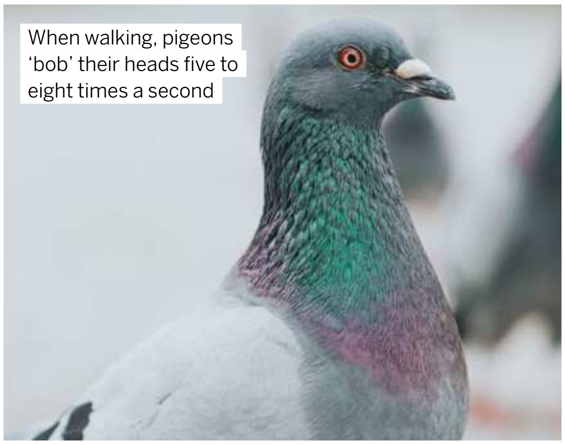
This handy guide is brimming with quick tips, life hacks and budget-friendly tricks to help you reduce your carbon footprint and live more sustainably

UNDERSTANDING PIGEONS

Dear **HIW**,
Could the reason why pigeons bob their heads be that it is a way to keep their head stationary to the ground so they can look for food while moving?
Julian Wiseman

This is a good guess, and also an accurate one. Pigeons' characteristic head bobbing is performed to stabilise their view of their surroundings. As a pigeon walks, it may look as though it is bobbing its head up and down, but it is pushing its head forward, in line with the ground. When it steps, its head is pushed forward and then held still as it waits for the body to catch up. During the time when the head is stationary, the bird has a moment to visually process its surroundings.

To discover the reasons for this trait, scientists carried out a treadmill experiment in 1978. When pigeons were placed on a treadmill, their visual surroundings remained the same. As they were still walking, but remaining stationary, they had no reason to constantly process their surroundings. For this reason, the pigeons analysed stopped bobbing their heads when walking on a treadmill.


When walking, pigeons 'bob' their heads five to eight times a second

AIRCRAFT AUDIO

Dear **HIW**,
Why is the noise from small aeroplanes so loud?
Stephen Conn

Though small planes can have smaller engines, noise from them is loud because they function in the same way. The engines work by sucking in air through a fan. It's compressed to increase the pressure, which helps increase the fuel combustion rate. After combustion, the air is released at high speeds. This causes loud pressure waves to form in the air. As planes are insulated and airtight, air inside isn't impacted like the air outside. While you can still hear the mechanical sounds of the engine from inside, noises caused by air turbulence are much less noticeable.

Mufflers can reduce the noise the engines make

NEXT ISSUE

ISSUE 170

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Tea bags are usually made of filter paper

SPILL THE TEA

Dear **HIW**,
What is the process from tea leaf to tea bag?
Oliver Robst

Tea leaves come from the plant *Camellia sinensis*. Once the leaves are picked, they are spread over a thin layer and aired for around 20 hours. This process is called withering and causes the leaves to turn a more coppery colour. Air oxidises the leaves' main active ingredient – polyphenols or tannins – during this step. Next, the leaves are crushed and twisted by hand or machine, releasing some of their juices before being torn into smaller pieces and dried. The drying process traps the flavour in the leaves and makes them dark black in colour. Depending on the type of tea being produced, the leaves are further cut into different sized pieces. Finally, tea leaves are usually blended with other types of tea leaves to achieve the desired flavour, before being wrapped in a fine mesh – the tea bag.

This is what the network of underfloor heating pipes looks like before the floor is laid on top

BATHROOM TECH

Dear **HIW**,
I recently went somewhere that had heated floors in the bathrooms. What causes the floor to heat up?
Bailey Gatard

Underfloor heating is a good way to evenly distribute heat in a home, as heated water runs through evenly spaced pipes below the floor. Unlike common central heating systems that use radiators to heat from one area of a room, underfloor heating can spread heat across the entire floor surface. It's controlled using a thermostat and requires water to be heated to lower temperatures than that in radiators.

WE ASKED YOU

This month on social media, we asked you: What is the best trick you have taught a pet?

@JONESY_RHYS06

I taught my dog to stop and wait for me before crossing any road

@FORD.STAN2021

Heel where the dog can stay by my side until told and retrieving

@NIKO

Taught my three-legged cat to sit, sadly she can't stand on her back legs though

@AESTHETICALLY_AJ

I taught my hamster to do monkey bars across the cage and run through tunnels

MYLES OWEN

I taught my dog to shake my hand

CHELSIE P

My cat can fetch like a dog

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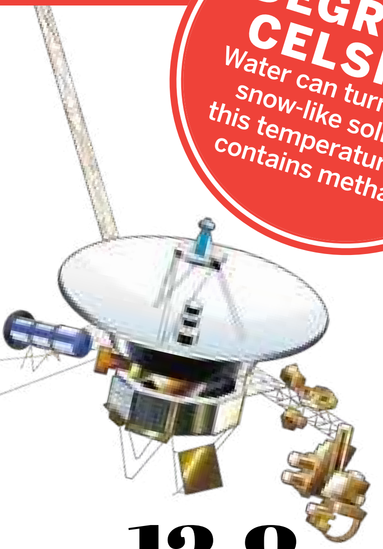
FAST FACTS

Amazing trivia that will blow your mind



14,000 YEARS

Voyager 1 won't leave everything that orbits the Sun behind for a long time yet

0.002 MILLIMETRES

If you rolled gold into a very thin foil, you could see sunlight through it

THE PLANET MERCURY IS SHRINKING

20 DEGREES CELSIUS

Water can turn into a snow-like solid at this temperature if it contains methane

13.8 BILLION YEARS

Every hydrogen atom in your body is as old as the universe

45,500 TONNES

The world's biggest land vehicle, the RWE Bagger 288 excavator, weighs almost as much as the Titanic did

4

Nine-banded armadillos always give birth to identical quadruplets

25 billion

Americans throw away billions of Styrofoam cups every year

'ROBOT' COMES FROM A CZECH WORD MEANING 'FORCED LABOUR'

Bees dance to tell nest mates where to find food

245.76 METRES

The record set by the Perseverance rover for longest drive in a single Martian day

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